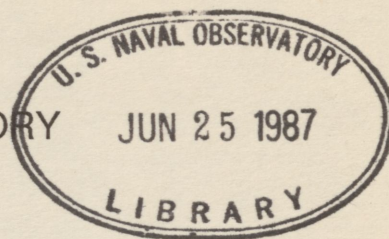


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UNITED STATES NAVAL OBSERVATORY

CIRCULAR NO. 171



U. S. Naval Observatory, Washington, D. C. 20392

February 19, 1987

Computer Programs for Sun and Moon Illuminance
With Contingent Tables and Diagrams

by

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INTRODUCTION

There is an ever increasing need for quantitative information concerning everyday astronomical events as they affect the range of private, civil and military activities. The information most needed is usually one or a combination of the following:

1. rise and set times of the Sun and Moon,
2. beginning and ending times of twilight,
3. total number of daylight hours,
4. maximum height of the Sun or Moon above the horizon with corresponding time of occurrence,
5. at specific instants, the angular distance of the Sun or Moon from the horizon and from a cardinal direction,
6. the amount of natural light at a designated time of day or night.

These data not only may differ from day to day (continuously in the case of 5. and 6.), but also differ appreciably as experienced at one place on the Earth as opposed to another, even at the same instant.

Despite the calculational complexities implied, it is possible not only to satisfy the needs for all such data in a straightforward way, but also to place appropriate tools for producing the data directly into the hands of those who need it. This publication is intended for a large number of people who have requirements for the type of data listed, but whose education has placed no special emphasis on astronomy. In what follows there are the means for calculating the needed information either by one of the self-contained computer routines provided, or by use of tables, diagrams (also included) and simple arithmetic. There is no requirement to understand the theory of the calculations; and the mathematical development is not given. To properly specify the quantities required by the calculations and to properly interpret the results however, the associated terminology should be familiar. Section I, therefore, is a list and discussion of terms.

Electronic computing has steadily become more accessible and inexpensive. Accordingly, three versions of a self-contained computing routine are described and provided in Section II. The first is a FORTRAN program for use with a variety of personal (and larger) computers for which FORTRAN compilers are available. A version in BASIC is provided to use with personal computers for which that programming language is appropriate. A third program, also in BASIC (but in a separate dialect) is given. It was designed for so-called pocket computers and powerful, programmable calculators which incorporate BASIC interpreters. For successful implementation of a computer routine, the user must learn how to use the specific device and must satisfy the syntax requirements of its compiler or interpreter.

Use of a computing device is not always possible. But it is possible to obtain the same data, at least for the Sun, from the tables and diagrams which are included here, with instructions, as Section III.

The methods used to construct the tables, graphs and computer codes are approximate and give times of events to the nearest minute and angles to the nearest degree. At latitudes less than 60 degrees, the output of the computer routines should agree with more refined calculations to within one or two minutes of time. The tables may be expected to give less precise times (up to four minutes in certain cases) on account of those compromises in their construction which maintain simplicity. At extreme North and South latitudes more exacting calculations are generally necessary to achieve one minute of time precision; and in comparisons, the computer routines provided here produced errors of up to four minutes and, in one case, failed to find a phenomenon altogether. Although it is possible to improve the precision of both the computer procedure and the tables, the improvements are not justified for several reasons:

1. the price to be paid would be much larger, slower computer code in the first instance, and a lengthy, complex table look-up and calculation process in the second;
2. the user would be required to specify geographic coordinates and the instantaneous orientation of the Earth in space, define the actual terrain and measure atmospheric parameters to an accuracy that is not attainable except in extraordinary circumstances;
3. rising, setting and twilight are always physically uncertain to some extent, and definitely so at extreme latitudes;
4. a critical examination of the conduct of any human activity almost always demonstrates that very precise times of astronomical events and precise light levels are simply not needed.

The computer and tabular procedures were designed to be valid for the 30 year period beginning at 1985. If used beyond this interval, the degradation in precision will be gradual but definite.

SECTION I

Description of Terms

This section is meant to be read from the beginning. Terms are introduced as needed or as they occur; consequently, they are not in alphabetical order.

Meridian: At any point on the Earth one might imagine a line that passes through that point and meets the North and South poles. Such a line, known as the meridian, also intersects the Earth's equator at right angles. Any point on the Earth has only one meridian, but each meridian passes through many points.

Latitude, Longitude: In order to unambiguously specify the location of a point on the Earth, two numbers (called coordinates) are needed. One of the numbers is the latitude, or the distance of the point from the equator. Latitude is expressed as an angle and measured northward or southward from zero degrees at the equator, along the meridian of the point, to the point itself. The other required number is the longitude, which is the distance of the meridian of the point from a reference (prime) meridian. Longitude is also expressed as an angle, and it is measured eastward or westward, from the prime meridian which passes through Greenwich, England, to the meridian of the point of interest. In this system of coordinates, the maximum possible latitudes are 90 degrees North, which is the position of the North Pole, and 90 degrees South, which corresponds to the South Pole. At 180 degrees West or East of the prime meridian is the International Date Line (certain parts of the Date Line depart from 180 degrees in order to accommodate geographic boundaries) and 180 degrees is the maximum value (limit) of longitude. See Figure 1.

The latitude and longitude of a place must be known in order to use the materials in the next two sections. There are many sources for coordinates. For example, an atlas or gazetteer is a convenient reference. Survey records as well as maps and charts issued by governments are usually obtainable. Coordinates may be obtained directly from various navigation systems now in use; certainly during long distance travel in open ocean the navigation-determined position is the only source. Appendix A to this publication lists coordinates for many locations in the United States. The user should be aware that the conventional manner of stating coordinates is degrees, minutes (and sometimes also seconds) of arc. For computer input degrees and decimals of a degree is the more convenient form.

Date, Time: The complete statement of an event such as sunset or an instantaneous position such as the altitude of the moon, relative to a location on the Earth, must include the date (year, month, day) and time of day. Specification of the date (in the Gregorian Calendar) poses no special problem; but one complication may arise and it will be discussed below. The time of day may be stated in several ways. Local Mean Time, although not an everyday term, arises naturally during the

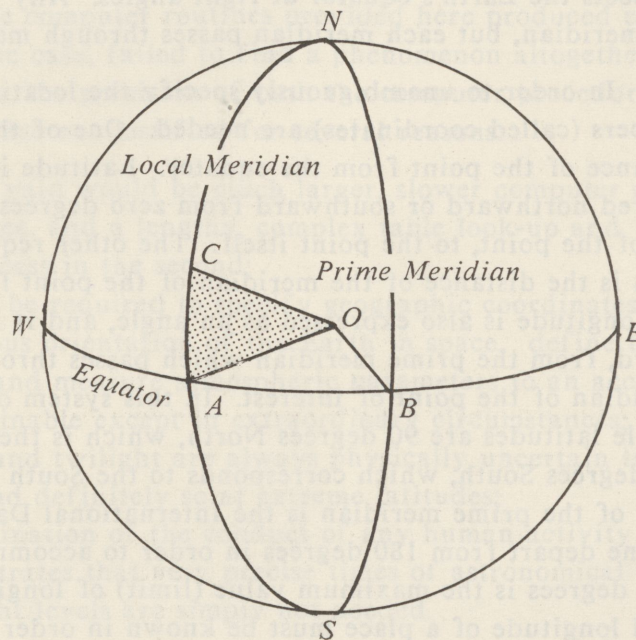


Figure 1 -- In this representation of the Earth, the North and South poles are at N and S, the equator is denoted by the arc WABE and the center of the Earth is at point O. Arc NCAS is the Local Meridian of the point C on the surface of the Earth; arc NBS is the Prime Meridian. Arc AC is the latitude of point C and is equal to the angle between the lines OC and OA. Arc BA is the longitude of point C and equal to the angle between the lines OB and OA.

procedures of Sections II and III. It is a measure of time referred to the meridian of the location of interest. As such, it is an isolated time measure of no importance to any other meridian. Times which are the input and output quantities of the computer routines may be expressed as Local Mean Time at the users discretion.

The most widely used system of specifying time is that of Zone Time or Standard Time. In that system, the Earth's 360 degree circumference is divided into 24 zones; and at all locations within each zone, all clocks are set to the same hour and minute. From any zone to the next adjacent zone, the Standard Time differs by exactly one hour. The geometrically obvious method for dividing the Earth into 24 zones is to place the boundaries at integral multiples of 15 degrees in longitude. In practice, the limits are established by considerations of commerce, transportation and political boundaries. On a global scale, the departures from uniform 15 degree divisions are small, and the methods of the next two sections provide for time adjustments based on zones that are exactly 15 degrees apart. An additional practical complication for the Standard Time zone system is a seasonal one in which the legal time for a political entity may be temporarily advanced by one or more hours. The dates of the year when these periods are in effect vary among the countries of the world which use such Daylight (Savings) or Summer Time and no general guidelines can be given for converting to and from Standard Time, except to note the necessity for the user to maintain awareness.

Universal Time, equivalent to the previously used Greenwich Mean Time for ordinary purposes, is the time kept on the Greenwich meridian -- at zero degrees longitude. It is widely used elsewhere, especially for purposes of long distance communication, since it avoids questions of zone boundaries and advanced time. The computer routines of Section II incorporate provisions for the use of Universal Time, under control of the user, and a table is given in Section III for adjusting among Mean, Zone and Universal Time systems for calculations without a computer.

When the longitudes of two places differ considerably and Universal Time is used, it is convenient to maintain time in a 24 hour notation, as it eliminates the suffix A.M. or P.M. from calculations and thereby reduces the chance for blunders. In the 24 hour notation, which maintains its advantage when computing with zone or mean time, the hours from midnight beginning the day until noon are the same as ordinary clock time. From noon until the end of the day, the hours are denoted by the numerals 12 through 23. When this system is used, the minutes part of the hour are appended to the hour to form a 4 digit number, without a colon separating the two. Thus, for example, 8:15 A.M. is written 0815 and 9:47 P.M. becomes 2147. The advantages of the 24 hours notation are so great that it is used throughout the remainder of this publication.

When the end result of calculation by the methods of the next sections produce one or more times exceeding 24 hours, the time or times may be adjusted by 24 hours provided the calendar date is advanced by one day. The computer routines should

never yield negative times, but the calculations of Section III may. In those cases, 24 hours may be added to make the times positive, provided the calendar date is also retarded by one day.

Meridian Passage: For any specific meridian, the Sun will cross it at some instant during the course of a day. Put another way, at any arbitrary time during a day, the Sun is crossing some meridian of the Earth. These statements are true even for arctic regions where the Sun may not be visible for months. Generally, the same statements may be made for the Moon. However, about once per month the Moon may cross a particular meridian a little before the midnight beginning a day and again a little past the midnight beginning the next day, so that there is no crossing on the day itself. Neither the Sun nor the Moon cross any specific meridian at exactly the same time every day; but since the crossings are significant in several applications, the times of occurrence may be calculated. The time when the Sun or Moon crosses the meridian of a place is designated meridian passage.

Horizon: Wherever one is located on the surface of the Earth, the Earth in the immediate vicinity appears essentially as a flat plane, while the sky appears much like the interior of a sphere or dome. The horizon is the intersection of the sky with the plane and appears to be a large circle with its center at the observer, just as the sky appears as one-half of a large sphere also centered at the observer.

Rise, Set: During the course of a day the Earth rotates once on its axis causing the phenomena of rising and setting. All celestial bodies, stars and planets included, seem to appear in the sky at the horizon to the East of any particular place, then to cross the sky and again disappear at the horizon to the West. The most noticeable of these events, and the most significant in regard to ordinary affairs, are the rising and setting of the Sun and Moon. Because the Sun and Moon appear as circular disks and not as points of light, a definition of rise or set must be very specific, for not all of either body is seen to rise or set at once; and the quantitative information that is usually required is the time at which a rise or set occurs. Therefore, sunrise and sunset are considered to occur when the upper edge of the disk of the Sun appears to be exactly on the horizon. The same statement applies to the Moon.

The times of rising and setting produced by the methods in this publication refer to the upper edge of the Sun or Moon. In addition, the computed times are for a horizon that is unobstructed relative to the location of interest, the atmospheric conditions are average and the location is in a level region on the Earth's surface.

For points on the Earth North of the Arctic Circle and South of the Antarctic Circle, rising and setting do not occur at an unbroken daily interval. There are days when the Sun and Moon do not rise or do not set. In limiting cases during the solar year, and during the lunar month, rising and setting are physically uncertain at such extreme latitudes.

Length of the Day: The total number of hours of daylight refers to the interval from the moment of sunrise until that of sunset. The meaning of the expression length of the day is somewhat arbitrary since there is some indirect sunlight available before sunrise and after sunset. Associating the length of the day with the discrete events of rise and set permits a definite measure of time to be assigned to the interval of daylight.

Twilight: Before sunrise and again after sunset there are periods of time, twilight, during which there is natural light provided by the upper atmosphere, which scatters sunlight. Some outdoor activities may be conducted without artificial illumination during these periods, and it is useful to have some means to set limits beyond which a certain activity must be assisted by artificial lighting if possible or, if not, then terminated. The major determinant of the amount of natural light during twilight is the atmosphere. Nevertheless, it is possible to establish useful though necessarily approximate limits applicable to large classes of activities by considering only the position of the Sun below the local horizon. Several arbitrary but reasonable definitions have evolved. Thus, *civil twilight* begins in the morning and ends at sunrise or begins at sunset and ends in the evening when the Sun is geometrically six degrees below the local horizon. Before morning civil twilight and after evening civil twilight, artificial illumination is ordinarily required. *Nautical twilight* begins in the morning and ends in the evening when the Sun is geometrically 12 degrees below the horizon. As the name implies, the principal use of the term nautical twilight is in navigational astronomy, and during the intervals between civil twilight and nautical twilight the brightest stars are visible and the sea horizon is clearly defined. Before morning nautical twilight and after evening nautical twilight the horizon is generally not visible and cannot be used as a reference without aided vision. *Astronomical twilight* begins and ends when the Sun is geometrically 18 degrees below the horizon. It is of significance principally in observational astronomy and indicates those times when scattered Sunlight on a horizontal surface becomes approximately equivalent to the light of the night sky. Times of civil and nautical twilight are provided by the computer routines in Section II and from the tables of Section III. The amount of available light during twilight is so greatly dependent upon the atmosphere, and especially upon cloudiness and haze, that only the most conservative approach to interpreting the times of twilight is justified when considering outdoor activity.

Altitude: As in the case of a position on the Earth, two coordinates are required to specify the position of an object on the sky. For convenience, one coordinate is measured in the sky and is known as altitude (in some applied sciences it is called elevation). The other coordinate is measured along the horizon on the plane of the observer, which is the other "half" of the observer's "universe." From the point that is directly above the location of interest (position of the observer) an arc (curved line) may be drawn through the point occupied by the object in the sky and extended to the horizon. The arc meets the horizon at a 90 degree angle and

is, therefore, perpendicular to the horizon. The altitude is an angle measured along the arc from the point where the arc meets the horizon, upward to the point occupied by the celestial object. The maximum altitude that an object may possibly have is 90 degrees, when it is directly above the geographic point of interest, and the object is then said to be "in the zenith." When meridian passage of an object occurs, the altitude is (or is nearly) a maximum (not usually 90 deg.) and the altitude at that instant takes on special significance to navigation and surveying. The Sun's altitude at meridian passage also has special interest in solar energy studies. See Figure 2.

Azimuth: On the horizon plane of an observer, or at some other location of interest, the meridian provides a North, South reference line. It may be thought of as a straight line extending from the observation point to true North (or South). Another straight line may be imagined to connect the observation point to the point on the horizon from which altitude is measured. The angle between these two lines is called the azimuth (of the object in the sky). The angle is measured along the horizon from North (zero degrees) toward East (90 degrees), and completes 360 degrees around the entire horizon. Azimuth, with altitude, allows the complete specification of a point or object in the sky, relative to a point or location on the Earth. See Figure 2.

Illuminance: This term may be defined as the flux received on a unit area of a surface. Flux is defined as the amount of radiation in a unit of time, usually the second. In the context of this publication, the definitions require qualification. Here, we refer to radiation only in the visible portion of the electromagnetic spectrum; that is, radiation capable of stimulating the human sense of sight. The illuminance calculated within the computer routines, and exhibited graphically in Section III, refers to visible natural light only. Further, the light of the sky is included and, therefore, the sea level, horizontal surface is assumed to be exposed to all parts of the sky. In ordinary terms then, illuminance is the amount of natural light reaching the surface of the Earth. The illuminance is given in lux, or lumens per square meter. The older term foot-candle may be more familiar to some, and to obtain illuminance in foot-candles, divide the quantity given in lux by 10.764. In addition to the restrictions already mentioned, the condition of the atmosphere modifies the illuminance to a considerable degree. This is accommodated in a rough way by the computer routines and graphs. At the user's option, the values of illuminance are divided by the numbers assigned to the conditions stated:

- 1 - Average clear sky, less than 70 percent covered by (scattered) clouds; the direct rays of the Sun or Moon are unobstructed relative to the location of interest.
- 2 - The Sun or Moon easily visible but direct rays obstructed by thin clouds.
- 3 - The direct rays of the Sun or Moon are obstructed by average clouds.
- 10 - Dark stratus clouds cover the entire sky.

The recommended approach to interpreting calculated illuminance is to consider the numbers as threshold values which, without additional knowledge, determine only whether a particular activity should not be planned or carried out. Even simple questions such as driving without headlamps, or detecting and identifying distant objects cannot be completely decided by knowledge of the illuminance alone. Other information specific to the illuminated surfaces, the nature of the activity, the conditions of vision, and other immediate circumstances must be included in planning and decision making processes.

The value of the illuminance calculated by the computer routines may appear in the output as a number with as many as 10 digits. Only the first two digits are significant, the remainder are necessary to accommodate the extreme variability of the illuminance - 124000 lux to .0005 lux.

Calculation of illuminance is described in more detail in Appendix B.

Percent of the Moon Illuminated: Considering the Moon as a circular disk, the ratio of its illuminated area to its total area is the fraction illuminated. The percent illuminated is the same number multiplied by 100. At New Moon the percent illuminated is 0; it is 50 at First and Last Quarters, and 100 at Full Moon. Percent of the Moon illuminated is produced by the computer routines; but independently of the fraction or percent illuminated, the amount of light provided by the Moon may vary by a factor of 300, depending upon the Moon's altitude above the horizon. The percentage illuminated, therefore, is of value principally during the initial stages of planning, preferably when it is available in the form of a daily or half-daily tabulation.

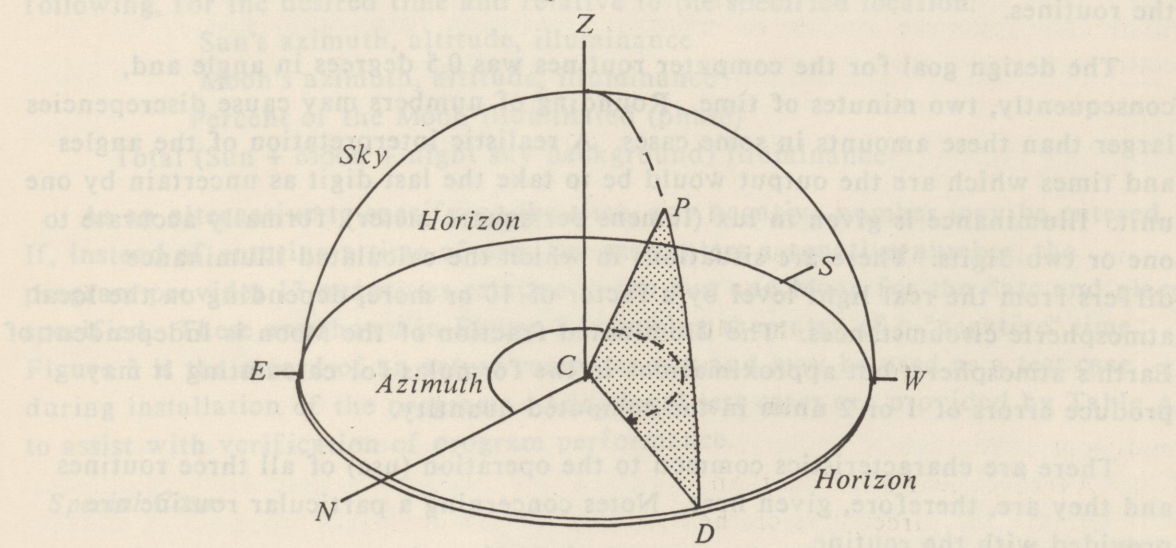


Figure 2 -- C is a point on the Earth's surface. The horizon plane, centered at C, is represented by ENDWS. The sky is shown by the arcs EZW and ZPD. The point directly overhead at C is the zenith (Z) and the direction of the vertical at C is CZ. P is the position of the Sun or Moon with direction CP as seen from C. The altitude of P is arc DP on the sky and equal to the angle between the lines CP and CD. Azimuth is the angle measured from line CN, positive eastward on the horizon plane, to line CD.

SECTION II

Computer Programs

The purpose of this section is to provide three self-contained routines for use with computers and powerful programmable calculators. The first is a FORTRAN code which was tested by compiling and executing on a large so-called main-frame computer, and with no changes, on two personal computers of different manufacture. The second version of the code is written in BASIC and was tested on three personal computers of different manufacture without modification, and two additional devices after some revisions. The third routine, again in BASIC, was written and tested on a scientific programmable calculator.

Despite the number and variety of computing devices now available, the FORTRAN and BASIC languages have much in common from one system to another. Differences among compilers and interpreters do exist in addition to machine architecture differences, however. For that reason, the computer codes given on the following pages have been kept simple and have not been optimized. In adapting them to one particular device or another, any required changes should be simple and straightforward (syntax, for example). Nevertheless, the burden of making the routines workable necessarily belongs to the user and the Naval Observatory cannot undertake to advise anyone concerning computers, software systems or alterations to the routines.

The design goal for the computer routines was 0.5 degrees in angle and, consequently, two minutes of time. Rounding of numbers may cause discrepancies larger than these amounts in some cases. A realistic interpretation of the angles and times which are the output would be to take the last digit as uncertain by one unit. Illuminance is given in lux (lumens per square meter), formally accurate to one or two digits. There are situations in which the calculated illuminance differs from the real light level by a factor of 10 or more, depending on the local atmospheric circumstances. The illuminated fraction of the Moon is independent of Earth's atmosphere, but approximations in the formulas for calculating it may produce errors of 1 or 2 units in the computed quantity.

There are characteristics common to the operation (use) of all three routines and they are, therefore, given here. Notes concerning a particular routine are provided with the routine.

The operation (execution) of the programs is primarily interactive. The programs prompt the user by displaying key words and phrases.

Dialog is initiated by the programs by requesting the longitude and latitude. These coordinates must be specified by the user as degrees and decimals. Although

it is possible to enter more precise values, accuracy of the programs is such that degrees and tenths are more than adequate.

Longitude must be entered as a positive number if East of the prime meridian and a negative number if West. North latitude is entered as a positive number and South latitude entered as a negative number.

Year, month and day are next requested. These are entered sequentially in order to provide flexibility to the programs. Their format is obvious from Figure 3 which shows a complete example (using the FORTRAN version).

The system of time measurement wanted by the user is then requested. The selection is to be specified by the user by entering one digit in response. It is important to remember that the next input after selecting the time system, and even the date itself, must be expressed in the selected system. Furthermore, all output quantities will be in the selected time system.

When the program prompts the user for time of day, it should be entered in the 24 hour clock scheme, as described in the Introduction.

With time of day entered as a positive number, the program will ask for an estimate of the sky condition. Reference should be made to the discussion of illuminance in the Introduction for an explanation. The number given by the user to the computer at this point will divide calculated illuminance before it appears as output.

Following the sky condition prompt and response, the program provides the following, for the desired time and relative to the specified location:

- Sun's azimuth, altitude, illuminance
- Moon's azimuth, altitude, illuminance
- Percent of the Moon illuminated (phase)
- Total (Sun + Moon + night sky background) illuminance

As an alternative to specifying the time, any negative number may be entered. If, instead of entering a time of day, the user enters a negative number, the program provides 13 quantities relative to the Sun and Moon for the date and place specified. These are shown in Figure 3 following the entry of a "negative" time. Figure 3 is the record of an actual computer run and may be used as a test case during installation of the programs. Additional test cases are provided by Table A to assist with verification of program performance.

Special Cases

1. At high northern or southern latitudes some events may not always occur. The Moon may remain above or below the horizon for more than one day. The Sun may remain above or below the horizon for months; and, during that period, twilight may not occur, or it may last for long periods of time. When these conditions prevail, one or more lines of output will be missing from the computer output. The user may determine the significance of the missing information by examining the altitude of

EXECUTION BEGINS...

INPUT LONGITUDE (DEG.), ENTER NULL LINE TO END)

?

-4.0

INPUT LATITUDE (DEG.)

?

58.0

INPUT YEAR (YYYY), NUMERAL

?

1987

INPUT MONTH (MM), NUMERAL

?

5

INPUT DAY (DD), NUMERAL

?

11

INPUT TIME ZONE SELECTION

0 => TIME IS UT (GMT)

1 => TIME IS STANDARD (ZONE) TIME

2 => TIME IS LOCAL MEAN TIME

?

0

INPUT TIME OF DAY AS HOURS AND MINUTES OF 24 HOUR CLOCK (HHMM), OR
INPUT ANY NEGATIVE NUMBER TO COMPUTE PHENOMENA (RISE/SET, ETC.), OR
INPUT NULL LINE TO END

?

2215

INPUT SKY CONDITION

1 => SUN/MOON VISIBLE, SKY < 70% OVERCAST

2 => SUN/MOON OBSCURED BY THIN CLOUDS

3 => SUN/MOON OBSCURED BY AVERAGE CLOUDS

10 => SUN/MOON OBSCURED BY DARK STRATUS CLOUDS (RARE)

?

1

AT -4.0 DEG LONGITUDE, 58.0 DEG LATITUDE

DATA FOR 1987, MONTH 5, DAY 11, AT 2215 HOURS

SOLAR AZIMUTH (DEG.) 332

SOLAR ALTITUDE (DEG.) -10

SOLAR ILLUMINANCE (LUX) 0.0278

LUNAR AZIMUTH (DEG.) 172

LUNAR ALTITUDE (DEG.) 18

LUNAR ILLUMINANCE (LUX) 0.0317

(97% OF MOON IS ILLUMINATED)

TOTAL ILLUMINANCE (LUX) 0.0600

Figure 3 -- Interactive Input, Output (FORTRAN).

INPUT TIME OF DAY AS HOURS AND MINUTES OF 24 HOUR CLOCK (HHMM), OR
 INPUT ANY NEGATIVE NUMBER TO COMPUTE PHENOMENA (RISE/SET, ETC.), OR
 INPUT NULL LINE TO END

?

-1

AT -4.0 DEG LONGITUDE, 58.0 DEG LATITUDE

DATA FOR 1987, MONTH 5, DAY 11

TIME OF SOLAR MERIDIAN PASSAGE 1212

ALTITUDE AT MERIDIAN PASSAGE (DEG.) 50

TIME OF SUNRISE 0402

TIME OF SUNSET 2025

TOTAL HOURS AND MINUTES OF DAYLIGHT 1623

TIME BEGINNING CIVIL TWILIGHT 0309

TIME ENDING CIVIL TWILIGHT 2118

TIME BEGINNING NAUTICAL TWILIGHT 0144

TIME ENDING NAUTICAL TWILIGHT 2246

TIME OF LUNAR MERIDIAN PASSAGE 2248

ALTITUDE AT MERIDIAN PASSAGE (DEG.) 18

TIME OF MOONRISE 1757

TIME OF MOONSET 0318

INPUT LONGITUDE (DEG.), ENTER NULL LINE TO END)

?

Figure 3 -- continued.

the Sun or Moon at meridian passage using the following scheme:

<u>missing output:</u>	<u>alt. at mer. pass:</u>	<u>signifies:</u>
rise/set	{ positive { negative	{ body continuously above horizon { body continuously below horizon
civil twilight	{ Sun alt. -6 deg. or greater { Sun alt. less than -6 deg.	{ twilight lasts all night { civil twilight does not occur
nautical twilight	{ Sun alt. -12 deg. or greater { Sun alt. less than -12 deg.	{ twilight lasts all night { darkness exceeds 24 hours

Since the Earth and Moon are in continuous motion, the program tests are not infallible at extremes of latitude. For limiting cases, the calculations may deviate in the sense that predicted events may not actually take place. Or, they may occur when the program tests indicate their absence. More exacting calculations are possible, but the improvement in reliability and accuracy is marginal for the plain reason that physical conditions at the extreme latitudes render the actual occurrence of events uncertain. Also, this may be easily seen by reference to the graphs of Section III where, for example, at latitudes above 65 degrees, the track of the Sun is seen to intersect the horizon at very shallow angles during certain times of the year.

2. About once per month at any latitude, there will be a 24 hour day during which the Moon does not cross the meridian. In this case, the Moon's meridian passage will appear in the program output with a time greater than 24 hours. This is normal and merely signifies that the next meridian passage after the beginning of a day will be on the following day. Moonrise and moonset may also appear with times exceeding 24 hours. These are also normal events, with a period of about one lunar month, and can occur at any latitude.
3. At high latitudes, the Moon may rise or set twice in one day. These are very infrequent events and the computer program will produce only one of the double phenomena.
4. Occasionally, a time of an event may appear with the minutes part equal to 60 (eg., 1060). Program code to avoid this possibility was deliberately omitted, as the significance of such numbers is obvious (1060=1100).
5. For some purposes it may be necessary to have the times of events expressed both in a local Zone Time and in Universal Time. The computer routines may be used to compute the times in both systems. Some results, when compared, may appear discordant, however. For an illustration, consider the beginning and end of nautical twilight computed for 1986 September 13 at longitude 77 deg. West and latitude 39 deg. North. With Zone Time specified, the results are 0449 and 1918. With UT specified, the results are 0949 and 0020. It is known that the Zone Time differs from UT by exactly 5 hours, and it is perfectly correct to add 5 hours to the Zone Time to obtain the UT times. Adding 5 hours to the Zone Times of the events produces 0949 and 2418. The second number exceeds 24 hours and can be written 0018 provided the date is increased by one day. It is also correct procedure to subtract 5 hours from the UT times to obtain the Zone Times. The results are then 0949-0500 = 0449; and 0020-0500 = -0440, or 1920 provided the date is retarded by one day. The results are collected in the following scheme for time ending nautical twilight:

<u>September:</u>	<u>12</u>	<u>13</u>	<u>14</u>
Zone Time:	1920	1918	
Universal Time:		0020	0018

It is seen that, for September 13, the computer programs have given results that do not refer to the same, identical event. Once a date is specified within the computer programs, it is invariant and the programs will not change it. The date is also that date associated with the time reference meridian specified by the time zone parameter which is entered by the user. Clearly, the proper interpretation of the data shown above is that the times computed for events depend upon the date which is kept at the reference meridian of the specified time zone. As a result, computed times of events which do not agree after adjustment for longitude difference may both be correct; each within its own frame of date and time measurement, but each referring to a separate event. In the illustration, the

end of nautical twilight for the given location on September 13, occurred at 1918 when reckoned according to date and time on the 75th meridian (September 14 at 0018 for date and time on the prime meridian). When reckoned according to date and time of the prime meridian it occurred on September 13 at 0020 (Sept. 12 at 1920 for date and time on the 75th meridian).

Table A, Test Cases for Program Certification

	I	II	III	IV	V	VI	VII
Longitude	+35.5	-150	-135.8	+180	+180	0	+39.5
Latitude	+46.0	+ 45	- 23.4	+ 70	+ 70	-68	+21.3
Year	1986	1986	1986	1987	1987	1988	1988
Month	7	9	12	2	2	1	8
Day	3	28	18	19	19	1	13
Zone	1	1	0	2	0	0	2
Hour	-1	-3	2100	-9	-1	-2	-3
Sky			1				
Sun merid. pass.	1142	1151		1214	0014	1203	1205
Alt. at m.p.	67	43		9	9	45	83
Sunrise	0352	0554		0819	2014		0538
Sunset	1932	1746		1610	0410		1831
Tot. daylight	1540	1152		0751	0756		1254
Beg. civil twi.	0314	0525		0712	1908		0514
End civil twi.	2010	1815		1717	0517		1855
Beg. naut. twi.	0223	0451		0601	1757		0447
End naut. twi.	2101	1849		1829	0629		1922
Moon merid. pass.	0835	0803		0340	1627	2216	1244
Alt. at m.p.	66	69		8	3	-7	81
Moonrise	0048	2504		2555	1356		0612
Moonset	1635	1558		0725	1835		1912
Hour							1831
Sky							1
Sun azimuth			346				286
Sun altitude			90				0
Sun illuminance			123786				697
Moon azimuth			282				278
Moon altitude			-62				8
Moon illuminance			0				0
(% illuminated)			94				1
Tot. illuminance			123786				697

The FORTRAN Program

The complete program consists of a main program, eight subroutines and three function statements. All are listed on succeeding pages. The following notes supplement those beginning with the first page of this section and apply to the FORTRAN code.

1. Precision

The program is in double precision for use with computers having 4 byte single precision words. If a computer can consistently maintain 8 significant digits during computation, then a single precision version of the program could be constructed.

2. Changes to the program

The leading statement IMPLICIT DOUBLE PRECISION (A-Z) may be changed to read IMPLICIT REAL*8 (A-Z) in order to satisfy syntax requirements of certain compilers.

If a single precision version of the program is desired and is possible, then all references to the following double precision functions must be converted to corresponding single precision references:

DABS DINT DASIN DCOS DEXP
DACOS DSIGN DSIN DTAN DATAN

Constants written in double precision format (D) convert to E format. The leading (IMPLICIT....) statement of the main program, subroutines and functions must be changed.

Program flow may be altered to some extent. As provided here, the flow follows certain ideas concerning probable usage. The main program statement following statement 580 may be changed to redirect execution. From GOTO 100, the statement may be altered to

GOTO 125 to rerun with a new year, month and day

GOTO 150 to input only a new month and day

GOTO 175 to input only a new day of the month

GOTO 200 to input a time during the year, month and day already specified

The main program statement following statement 805 may be altered from GOTO 200 to GOTO 125, or 150, or 175 with the same results as above. All of these changes will cause the program to produce data for the same longitude and latitude. To compute data for a different geographic place, at least one of the above GOTO statements must direct a transfer to statement 100.

3. Other changes

An experienced programmer might make changes to the program other than these described above. The programmer should be extremely cautious, however. Several of the variables are multiply-defined and certain computational sequences must not be disturbed or their results may be totally false. In the worst case, the end results may appear reasonable.

4. Operation

Once the program begins to execute, operation is interactive with prompting. The user should refer to Fig. 3 for an example, and is encouraged to reproduce the example at least once in order to gain familiarity with program usage.

```

100  WRITE (**) ' '
110  WRITE (**) ' '
120  READ (**) ' '
130  WRITE (**) 'INPUT YEAR (YYYY), NUMERICAL'
140  READ (**) 'Y'
150  WRITE (**) 'INPUT MONTH (MM), NUMERICAL'
160  READ (**) 'M'
170  WRITE (**) 'INPUT DAY (DD), NUMERICAL'
180  READ (**) 'D'
190  LT = DAYS(LO)
200  TO = 7
210  F = F*DR
220  SI = SIN(PI*F)
230  CI = COS(PI*F)
240  Z = 35*IX-INT(7*(IX+INT((IM-9)/(12)))/(4)+INT(372*IX/5)+ID-730534)
250  WRITE (**) 'INPUT TIME ZONE SELECTION, 1-12'
260  READ (**) 'Z'
270  WRITE (**) '0 => TIME IS UT (GMT)'
280  WRITE (**) '1 => TIME IS STANDARD TIME'
290  WRITE (**) '2 => TIME IS LOCAL MEAN TIME'
300  READ (**) 'X'
310  ST = 3
320  DT = 0
330  IF (Z.EQ.1.OOO) DT = (LT-15.000*INT((11+Z-200)/15.000))/C
340  *DESIGN(1.000,10) READ DTOS (100.0, 30.0) AT
350  WRITE (**) ' '
360  WRITE (**) ' '
370  WRITE (**) 'INPUT TIME OF DAY AS HOURS AND MINUTES OF 24.'
380  READ (**) 'HH:MM'
390  WRITE (**) ' '
400  WRITE (**) ' '
410  WRITE (**) ' '
420  WRITE (**) ' '
430  WRITE (**) ' '
440  WRITE (**) ' '
450  WRITE (**) ' '
460  WRITE (**) ' '
470  WRITE (**) ' '
480  WRITE (**) ' '
490  WRITE (**) ' '
500  WRITE (**) ' '
510  WRITE (**) ' '
520  WRITE (**) ' '
530  WRITE (**) ' '
540  WRITE (**) ' '
550  WRITE (**) ' '
560  WRITE (**) ' '
570  WRITE (**) ' '
580  WRITE (**) ' '
590  WRITE (**) ' '
600  WRITE (**) ' '
610  WRITE (**) ' '
620  WRITE (**) ' '
630  WRITE (**) ' '
640  WRITE (**) ' '
650  WRITE (**) ' '
660  WRITE (**) ' '
670  WRITE (**) ' '
680  WRITE (**) ' '
690  WRITE (**) ' '
700  WRITE (**) ' '
710  WRITE (**) ' '
720  WRITE (**) ' '
730  WRITE (**) ' '
740  WRITE (**) ' '
750  WRITE (**) ' '
760  WRITE (**) ' '
770  WRITE (**) ' '
780  WRITE (**) ' '
790  WRITE (**) ' '
800  WRITE (**) ' '
810  WRITE (**) ' '
820  WRITE (**) ' '
830  WRITE (**) ' '
840  WRITE (**) ' '
850  WRITE (**) ' '
860  WRITE (**) ' '
870  WRITE (**) ' '
880  WRITE (**) ' '
890  WRITE (**) ' '
900  WRITE (**) ' '
910  WRITE (**) ' '
920  WRITE (**) ' '
930  WRITE (**) ' '
940  WRITE (**) ' '
950  WRITE (**) ' '
960  WRITE (**) ' '
970  WRITE (**) ' '
980  WRITE (**) ' '
990  WRITE (**) ' '

```


The FORTRAN Program

```

IMPLICIT DOUBLE PRECISION (A-Z)
INTEGER IY,IM,ID,IH,L,I,K,N,J,IAZ,IHA
DIMENSION A(4), B(2)
RD = 57.29577951D0
DR = 1.0D0/RD
A(1) = -0.01454D0
A(2) = -0.10453D0
A(3) = -0.20791D0
A(4) = +0.00233D0
CE = 0.91775D0
SE = 0.39715D0
100 WRITE (*,*) ' '
    WRITE (*,*) ' '
    WRITE (*,*) 'INPUT LONGITUDE (DEG.), ENTER NULL LINE TO END) '
    READ (*,*,END=9999) LO
    WRITE (*,*) 'INPUT LATITUDE (DEG.)'
    READ (*,*) F
125 WRITE (*,*) 'INPUT YEAR (YYYY), NUMERAL'
    READ (*,*) IY
150 WRITE (*,*) 'INPUT MONTH (MM), NUMERAL'
    READ (*,*) IM
175 WRITE (*,*) 'INPUT DAY (DD), NUMERAL'
    READ (*,*) ID
    C = 360.0D0
    LI = DABS(LO)
    FO = F
    F = F*DR
    SI = DSIN(F)
    CI = DCOS(F)
    J = 367*IY-INT(7*(IY+INT((IM+9)/12))/4)+INT(275*IM/9)+ID-730531
    WRITE (*,*) 'INPUT TIME ZONE SELECTION'
    WRITE (*,*) ' '
    WRITE (*,*) '      0 => TIME IS UT (GMT)'
    WRITE (*,*) '      1 => TIME IS STANDARD (ZONE) TIME'
    WRITE (*,*) '      2 => TIME IS LOCAL MEAN TIME'
    READ (*,*) Z
    ZT = Z
    DT = 0
    IF (Z .EQ. 0.0D0) DT = -LO/360.0D0
    IF (Z .EQ. 1.0D0) DT = (LI-15.0D0*DINT((LI+7.5D0)/15.0D0))/C
    &      *DSIGN(1.0D0,-LO)
200 WRITE (*,*) ' '
    WRITE (*,*) ' '
    WRITE (*,*) 'INPUT TIME OF DAY AS HOURS AND MINUTES OF 24',
    &      ' HOUR CLOCK (HHMM), OR'
    WRITE (*,*) 'INPUT ANY NEGATIVE NUMBER TO COMPUTE PHENOMENA',
    &      ' (RISE/SET, ETC.), OR'
    WRITE (*,*) 'INPUT NULL LINE TO END'
    READ (*,*,END=9999) H
    IF (H .GE. 0.0D0) GOTO 600
    WRITE (*,205) LO,FO

```



```

205  FORMAT (' AT ',F6.1,' DEG LONGITUDE, ',F5.1,' DEG LATITUDE')
      WRITE (*,210) IY,IM,ID
210  FORMAT (' DATA FOR ',I4,', MONTH ',I2,', DAY ',I2)
      Z = J-0.5D0
      DO 580 L = 1, 4
          GOTO (260,390,390,250), L
250  C = 347.81D0
260  M = 0.5D0+DT
      K = 1
280  IF (L .LT. 4) K = K+1
          M = M-DT
          E = M-LO/360.0D0
          D = Z+E
          CALL CRCT (D,E,L,LO,C,DR,RD,CE,SE,U,DS,SD)
          M = M-U+DT
          GOTO (360,285,360,300,360,370), K
285  IF (M .GE. 0.0D0 .AND. M .LT. 1.0D0) GOTO 370
      GOTO 320
300  IF(M .GE. 0.0D0) GOTO 370
320  M = M-DSIGN(1.0D0,M)
360  K = K+1
      GOTO 280
370  H = DASIN(DCOS(F-DS))*RD
      IF(L .EQ. 4) H = H-.95*DCOS(H*DR)
      CALL REFR (H,DR,HA)
390  CALL HORX (A,L,SI,SD,CI,DS,C,RD,H)
      B(1) = M-H
      B(2) = M+H
      DO 560 I = 1, 2
          K = 2*I-3
          N = 1
450  IF (L .LT. 4) N = N+1
          B(I) = B(I)-DT
          E = B(I)-LO/360.0D0
          D = Z+E
          CALL CRCT (D,E,L,LO,C,DR,RD,CE,SE,U,DS,SD)
          CALL HORX (A,L,SI,SD,CI,DS,C,RD,H)
          B(I) = B(I)+K*H-U+DT
          GOTO (550,460,550,470,550,560), N
460  IF (B(I) .GE. 0.0D0 .AND. B(I) .LT. 1.0D0) GOTO 560
      GOTO 480
470  IF (B(I) .GE. 0.0D0) GOTO 560
480  B(I) = B(I) - DSIGN(1.0D0,B(I))
550  N = N+1
      GOTO 450
560  CONTINUE
      CALL OUT (ZT,M,HA,B,L)
580  CONTINUE
      GOTO 100
600  WRITE (*,*) 'INPUT SKY CONDITION'
      WRITE (*,*) ' '
      WRITE (*,*) '1 => SUN/MOON VISIBLE, SKY < 70% OVERCAST'

```



```

WRITE (*,*) '2 => SUN/MOON OBSCURED BY THIN CLOUDS '
WRITE (*,*) '3 => SUN/MOON OBSCURED BY AVERAGE CLOUDS '
WRITE (*,*) '10 => SUN/MOON OBSCURED BY DARK STRATUS CLOUDS',
& ' (RARE)'
READ (*,*) SK
IH = DINT(H)
WRITE (*,205) LO,FO
WRITE (*,610) IY,IM,ID,IH
610 FORMAT (' DATA FOR ',I4,', MONTH ',I2,', DAY ',I2,', AT ',I4.4,
& ' HOURS')
E = DEG(H/100.0D0)/24.0D0-DT-LO/360.0D0
D = J-0.5D0+E
N = 1
CALL SUN (D,DR,RD,CE,SE,T,G,LS,AS,SD,DS)
T = T+360.0D0*E+LO
660 IF (N.EQ. 2) CALL MOON (D,G,CE,SE,RD,DR,V,CB,AS,SD,DS)
H = T-AS
CALL ALTAZ (DS,H,SD,CI,SI,DR,RD,AZ)
Z = H*DR
H = H-0.95D0*(N-1)*DCOS(H*DR)
CALL REFR (H,DR,HA)
CALL ATMOS (HA,DR,M)
HA = DSIGN(DINT(DABS(HA)+0.5D0),HA)
GOTO (750,790), N
750 IS = 133775.0D0*M/SK
IAZ = DINT(AZ)
WRITE (*,751) IAZ
751 FORMAT (' SOLAR AZIMUTH (DEG.)',14X,I4.3)
IHA = DINT(HA)
WRITE (*,752) IHA
752 FORMAT (' SOLAR ALTITUDE (DEG.)',14X,I3)
WRITE (*,753) IS
753 FORMAT (' SOLAR ILLUMINANCE (LUX)',9X,F11.4)
N = 2
GOTO 660
790 E = DACOS(DCOS(V-LS)*CB)
P = 0.892D0*DEXP(-3.343D0/((DTAN(E/2.0D0))**0.632D0))+0.0344D0*
& (DSIN(E)-E*DCOS(E))
P = 0.418D0*P/(1.0D0-0.005D0*DCOS(E)-0.03D0*DSIN(Z))
IL = P*M/SK
IS = IS+IL+0.0005D0/SK
IAZ = DINT(AZ)
WRITE (*,801) IAZ
801 FORMAT (' LUNAR AZIMUTH (DEG.)',14X,I4.3)
IHA = DINT(HA)
WRITE (*,802) IHA
802 FORMAT (' LUNAR ALTITUDE (DEG.)',14X,I3)
WRITE (*,803) IL
803 FORMAT (' LUNAR ILLUMINANCE (LUX)',9X,F11.4)
IHA = DINT(50.D0*(1.0D0-DCOS(E))+0.5D0)
WRITE (*,804) IHA
804 FORMAT (' (' ,I3,'% OF MOON IS ILLUMINATED)')

```



```

      WRITE (*,805) IS
805   FORMAT (' TOTAL ILLUMINANCE (LUX)',9X,F11.4)
      GOTO 200
9999  CONTINUE
      END

```

```

C-----
      SUBROUTINE CRCT (D,E,L,LO,C,DR,RD,CE,SE,U,DS,SD)
      IMPLICIT DOUBLE PRECISION (A-Z)
      INTEGER L
      IF (DABS(E) .GE. 1.0D0) E = E-DSIGN(1.0D0,E)
      CALL SUN (D,DR,RD,CE,SE,T,G,LS,AS,SD,DS)
      IF (L .EQ. 4) CALL MOON (D,G,CE,SE,RD,DR,V,CB,AS,SD,DS)
      T = T+LO+360.0D0*E
      T = T-DINT(T/360.0D0)*360.0D0
      U = T-AS
      IF (DABS(U) .GT. 180.0D0) U = U-DSIGN(360.0D0,U)
      U = U/C
      RETURN
      END

```

```

C-----
      SUBROUTINE SUN (D,DR,RD,CE,SE,T,G,LS,AS,SD,DS)
      IMPLICIT DOUBLE PRECISION (A-Z)
      T = 280.46D0+0.98565D0*D
      T = T-DINT(T/360.0D0)*360.0D0
      IF (T .LT. 0.0D0) T = T+360.0D0
      G = (357.5D0+0.98560D0*D)*DR
      LS = (T+1.91D0*DSIN(G))*DR
      AS = DATAN(CE*DTAN(LS))*DR
      Y = DCOS(LS)
      IF (Y .LT. 0.0D0) AS = AS+180.0D0
      SD = SE*DSIN(LS)
      DS = DASIN(SD)
      T = T-180.0D0
      RETURN
      END

```

```

C-----
      SUBROUTINE MOON (D,G,CE,SE,RD,DR,V,CB,AS,SD,DS)
      IMPLICIT DOUBLE PRECISION (A-Z)
      V = 218.32D0+13.1764D0*D
      V = V-DINT(V/360.0D0)*360.0D0
      IF (V .LT. 0.0D0) V = V+360.0D0
      Y = (134.96D0+13.06499D0*D)*DR
      O = (93.27D0+13.22935D0*D)*DR
      W = (235.7D0+24.38150D0*D)*DR
      SB = DSIN(Y)
      CB = DCOS(Y)
      X = DSIN(O)
      S = DCOS(O)
      SD = DSIN(W)
      CD = DCOS(W)
      V = (V+(6.29D0-1.27D0*CD+0.43D0*CB)*SB+(0.66D0+1.27D0*CB)*SD
&      -0.19D0*DSIN(G)-0.23D0*X*S)*DR

```



```

Y = ((5.13D0-0.17D0*CD)*X+(0.56D0*SB+0.17D0*SD)*S)*DR
SV = DSIN(V)
SB = DSIN(Y)
CB = DCOS(Y)
Q = CB*DCOS(V)
P = CE*SV*CB-SE*SB
SD = SE*SV*CB+CE*SB
AS = DATAN(P/Q)*RD
IF (Q .LT. 0.0D0) AS = AS+180.0D0
DS = DASIN(SD)
RETURN
END

```

```

C-----
SUBROUTINE HORX (A,L,SI,SD,CI,DS,C,RD,H)
IMPLICIT DOUBLE PRECISION (A-Z)
INTEGER L
DIMENSION A(4)
H = (A(L)-SI*SD)/(CI*DCOS(DS))
IF (DABS(H) .GT. 1.0D0) GOTO 5040
H = DACOS(H)*RD/C
RETURN
5040 H = 1.5D0
RETURN
END

```

```

C-----
SUBROUTINE ALTAZ (DS,H,SD,CI,SI,DR,RD,AZ)
IMPLICIT DOUBLE PRECISION (A-Z)
CD = DCOS(DS)
CS = DCOS(H*DR)
Q = SD*CI-CD*SI*CS
P = -CD*DSIN(H*DR)
AZ = DATAN(P/Q)*RD
IF (Q.LT. 0.0D0) AZ = AZ+180.0D0
IF (AZ .LT. 0.0D0) AZ = AZ+360.0D0
AZ = DINT(AZ+0.5D0)
H = DASIN(SD*SI+CD*CI*CS)*RD
RETURN
END

```

```

C-----
SUBROUTINE REFR (H,DR,HA)
IMPLICIT DOUBLE PRECISION (A-Z)
HA = H
IF (H .LT. (-5.0D0/6.0D0)) RETURN
HA = H+1.0D0/(DTAN((H+8.6D0/(H+4.42D0))*DR))/60.0D0
RETURN
END

```

```

C-----
SUBROUTINE ATMOS (HA,DR,M)
IMPLICIT DOUBLE PRECISION (A-Z)
U = DSIN(HA*DR)
X = 753.66156D0
S = DASIN(X*DCOS(HA*DR)/(X+1.0D0))

```



```

M = X*(DCOS(S)-U)+DCOS(S)
M = DEXP(-0.21D0*M)*U+0.0289D0*DEXP(-0.042D0*M)*(1.0D0+
& (HA+90.0D0)*U/57.29577951D0)
RETURN
END

```

```

C-----
SUBROUTINE OUT (ZT,M,HA,B,L)
IMPLICIT DOUBLE PRECISION (A-Z)
INTEGER I,L,IR1,IHA
DIMENSION B(2)
GOTO (3000,3050,3050,3260), L
3000 IR1 = DINT(TIMES(M))
IF (ZT .EQ. 1.0D0) THEN
  WRITE(*,*) '*** FOR DAYLIGHT (SUMMER) TIME ADD ONE HOUR ***'
END IF
WRITE (*,3001) IR1
3001 FORMAT (' TIME OF SOLAR MERIDIAN PASSAGE',6X,I4.4)
3030 IHA = DINT(DSIGN(DINT(DABS(HA)+0.5D0),HA))
WRITE (*,3031) IHA
3031 FORMAT (' ALTITUDE AT MERIDIAN PASSAGE (DEG.)',2X,I3)
3050 I = 1
3060 R = TIMES(B(I))
IF (R .GE. 4800.0D0 .OR. R .LT. 0.0D0) GOTO 3330
GOTO (3100,3120,3180,3200,3220,3240,3300,3320), 2*(L-1)+I
3100 IR1 = DINT(R)
WRITE (*,3101) IR1
3101 FORMAT (' TIME OF SUNRISE',21X,I4.4)
GOTO 3330
3120 IR1 = DINT(R)
WRITE (*,3121) IR1
3121 FORMAT (' TIME OF SUNSET',22X,I4.4)
R = B(2)-B(1)
IF (R .LT. 0.0D0) R = R+1
R = TIMES(R)
IR1 = DINT(R)
WRITE (*,3171) IR1
3171 FORMAT (' TOTAL HOURS AND MINUTES OF DAYLIGHT ',I4.4)
GOTO 3330
3180 IR1 = DINT(R)
WRITE (*,3181) IR1
3181 FORMAT (' TIME BEGINNING CIVIL TWILIGHT',7X,I4.4)
GOTO 3330
3200 IR1 = DINT(R)
WRITE (*,3201) IR1
3201 FORMAT (' TIME ENDING CIVIL TWILIGHT',10X,I4.4)
GOTO 3330
3220 IR1 = DINT(R)
WRITE (*,3221) IR1
3221 FORMAT (' TIME BEGINNING NAUTICAL TWILIGHT',4X,I4.4)
GOTO 3330
3240 IR1 = DINT(R)
WRITE (*,3241) IR1

```



```

3241  FORMAT (' TIME ENDING NAUTICAL TWILIGHT',7X,I4.4)
      GOTO 3330
3260  R = TIMES(M)
      IR1 = DINT(R)
      WRITE (*,3261) IR1
3261  FORMAT (' TIME OF LUNAR MERIDIAN PASSAGE',6X,I4.4)
      GOTO 3030
3300  IR1 = DINT(R)
      WRITE (*,3301) IR1
3301  FORMAT (' TIME OF MOONRISE',20X,I4.4)
      GOTO 3330
3320  IR1 = DINT(R)
      WRITE (*,3321) IR1
3321  FORMAT (' TIME OF MOONSET',21X,I4.4)
3330  I = I + 1
      IF (I .LT. 3) GOTO 3060
      RETURN
      END

```

```

C-----
      DOUBLE PRECISION FUNCTION TIMES (X)
      IMPLICIT DOUBLE PRECISION (A-Z)
      TIMES = DINT(100.0D0*DMS(X*24.0D0)+0.5D0)
      RETURN
      END

```

```

C-----
      DOUBLE PRECISION FUNCTION DMS (X)
      IMPLICIT DOUBLE PRECISION (A-Z)
      DMS = DINT(X)+6.0D0*(X-DINT(X))/10.0D0
      RETURN
      END

```

```

C-----
      DOUBLE PRECISION FUNCTION DEG (X)
      IMPLICIT DOUBLE PRECISION (A-Z)
      DEG = DINT(X)+((X-DINT(X))*10.0D0)/6.0D0
      RETURN
      END

```


The BASIC Program for Computers

This version of the program consists of a main program which begins at statement 10 and ends at statement 1210. There are several subprograms which are written in open style so that variables do not pass through calling sequences. One of these is embedded in the main program. Definition statements for such functions as *arccosine*, *arcsine* are at the beginning of the program, as required. These functions may be available in some interpreters. The notes which follow apply to the BASIC code for personal computers and supplement the general notes beginning with the first page of this Section.

1. Precision

The program is written using a mixed precision; that is, most of the program uses single precision. There are several calculations which produce large numbers, and to retain significance at the half-degree level, extended precision is required. The use of extended or double precision must be identified to the interpreter in some way. In the BASIC dialect given here, that is accomplished by appending the symbol # to certain variables and constants. There are some computers in which numbers are stored and manipulated with sufficient precision such that extended or double precision is not needed and is not an interpreter option. For such configurations of machine and language, the following statements should be edited and the symbol # deleted:

310, 430, 900, 1220, 1230, 1250, 1260, 1720,
1730, 1750, 1760, 1770, 1780, 1790, 1800.

2. Changes to the program

Syntax rules for BASIC interpreters vary considerably and not all possibilities can be explored here. Nevertheless, since it is to be expected that some changes will be required for implementation of the program, a few guidelines can be given.

It will be seen in the code that the words THEN and LET frequently appear in combination. In testing, it was found that LET was not required by one interpreter. Another interpreter required LET but not THEN. Still another, older interpreter required LET to precede any equality or equation statement and required it in combination with THEN in conditional statements. Obviously, the user should explore the possibilities and requirements of the particular machine/language combination for simplifications.

Many versions of BASIC allow multicharacter variable and function names to be defined. Of these, some versions will actually use only the initial two characters when referencing the function or variable. If this is not known to the programmer or user, the results can be unpredictable. In the worst case tested, some of the program output actually contained valid results. Should it be found that two character function and variable names are required, the program given here can be easily modified. Only function names, not variable names, need to be changed. In

order to avoid conflicts, the following functions could be renamed as shown:

ARCOS - RC

ARCSIN - RS

DEG - DG

DMS - DM

Of course, program references to the functions must be changed accordingly.

In addition to the restriction of two-character variable and user defined function references, the interpreter may offer an expanded set of commands. Unfortunately, corresponding to the expanded command set is a similarly enlarged list of words or acronyms which are described as reserved, protected, or privileged. Since it is not possible to predict which two-character combinations will infringe upon the reserved set of every computer/interpreter configuration, the program user must be aware of possible consequences. Those should be addressed in the literature describing the interpreter and its use. Often, infringement triggers syntax error messages, so that the offending variable may be readily found and redefined.

Some versions of BASIC do not allow function definitions by the user, but do provide the functions. The user should then modify this program so that the function ARCOS is replaced, where used, by whatever is provided for computing the *arccosine*. The *arcsine* function (ARCSIN) should be replaced likewise. The functions DEG and DMS can be re-defined as subroutines, and statements 890 and 1700 modified accordingly.

Statement 1100 requires that a trigonometric *tangent* be raised to the fractional exponent .632. As given here, the operation is specified by the symbol ^ (Specifically, the character is an ASCII hexadecimal 5E or decimal 94.) This is acceptable to several versions of BASIC; but in one dialect encountered, the required symbol for the same operation was a vertical arrow. The user should be aware of this and related variations of notation.

Program flow may be altered to some extent. As provided here, the flow reflects certain ideas concerning probable usage. Other modes may be more convenient for certain applications. The statements numbered 860 and 1200 may be changed to redirect execution:

GO TO 150 to initialize all input

GO TO 170 to input a new year, month, day, etc.

GO TO 180 to input a new month, day, etc.

GO TO 190 to input a new day, etc.

GO TO 300 to input a time during the year, month and day already specified.

Statement 1200 transfers control to 300. It may be changed to send control to statements 150, 170, 180 or 190, as above. At least one of the statements (860 or 1200) should direct a transfer to statement 150 if data for more than one location are to be computed during a session.

3. Other changes

An experienced programmer might make changes to the program other than those already described. However, caution must be used. Several variables are multiply-defined and certain computational sequences may not be disturbed or their results will be false. In the worst case, the end results may appear reasonable.

4. Operation

Once the program has been implemented, operation should proceed interactively with prompting by key words and phrases provided. The user should refer to Fig. 3 for an example of use. Output of the BASIC program will differ from the example in appearance, but not in data sequence or actual content.

The BASIC Program for Computers

```
10 DEF FNARCOS(ARG)=1.570796-ATN(ARG/SQR(1.-ARG*ARG))
20 DEF FNARCSIN(ARG)=ATN(ARG/SQR(1.-ARG*ARG))
30 DEF FNDEG(ARG)=INT(ARG)+((ARG-INT(ARG))*10.)/6.
40 DEF FNDMS(ARG)=INT(ARG)+6.*(ARG-INT(ARG))/10.
50 RD=57.29578
60 DR=1./RD
70 DIM A(4)
80 DIM B(2)
90 A(1)=-.01454
100 A(2)=-.10453
110 A(3)=-.20791
120 A(4)=.00233
130 CE=.91775
140 SE=.39715
150 INPUT"LONGITUDE IN DEG.";LO
160 INPUT"LATITUDE IN DEG.";F
170 INPUT"YEAR (4 DIGITS)";IY
180 INPUT"MONTH (NUMERAL)";IM
190 INPUT"DAY (NUMERAL)";ID
200 F=F*DR
210 C=360.
220 LI=ABS(LO)
230 SI=SIN(F)
240 CI=COS(F)
250 J=367*IY-INT(7*(IY+INT((IM+9)/12))/4)+INT(275*IM/9)+ID-730531.
260 INPUT"UNIVERSAL TIME = 0, ZONE TIME = 1, LOCAL MEAN TIME = 2";Z
270 DT=0.
280 IF Z=0. THEN LET DT=-LO/C
290 IF Z=1. THEN LET DT=-(LI-15*INT((LI+7.5)/15))/C*SGN(LO)
300 INPUT"HOUR (4 DIGIT NUMERAL ON 24 HOUR CLOCK)";H
310 Z0#=J-.5
320 IF H>0 THEN GOTO 870
330 PRINT"DATA FOR ";IY;"", MONTH ";IM;"", DAY ";ID
340 FOR L=1 TO 4
350 ON L GOTO 370,650,650,360
360 C=347.81
370 M=.5+DT
380 K=1
390 M=M-DT
400 E=M-LO/360.
410 GOSUB 430
420 GOTO 530
430 D#=Z0#+E
440 IF ABS(E)>=1 THEN LET E=E-SGN(E)
450 GOSUB 1220
460 IF L=4 THEN GOSUB 1720
470 T=T+LO+360.*E
480 T=T-INT(T/360.)*360.
490 U=T-AS
500 IF ABS(U)>180. THEN LET U=U-360.*SGN(U)
510 U=U/C
520 RETURN
```



```

530 M=M-U+DT
540 IF L<4 THEN LET K=K+1
550 ON K GOTO 600,560,600,580,600,620
560 IF M>=0. AND M<1. THEN GOTO 620
570 GOTO 590
580 IF M>=0. THEN GOTO 620
590 M=M-SGN(M)
600 K=K+1
610 GOTO 390
620 H=FNARCSIN(COS(F-DS))*RD
630 IF L=4 THEN LET H=H-.95*COS(H)
640 GOSUB 2160
650 GOSUB 2000
660 B(1)=M-H
670 B(2)=M+H
680 FOR I=1 TO 2
690 K=2*I-3
700 FOR N=1 TO 6
710 B(I)=B(I)-DT
720 E=B(I)-LO/360.
730 GOSUB 430
740 GOSUB 2000
750 B(I)=B(I)+K*H-U+DT
760 IF L<4 THEN LET N=N+1
770 ON N GOTO 820,780,820,800,820,830
780 IF B(I)>=0. AND B(I)<1. THEN GOTO 830
790 GOTO 810
800 IF B(I)>=0. THEN GOTO 830
810 B(I)=B(I)-SGN(B(I))
820 NEXT N
830 NEXT I
840 ON L GOSUB 1350,1400,1400,1610
850 NEXT L
860 GOTO 150
870 INPUT"SKY CONDITION = 1,2,3,10,";SK
880 PRINT"DATA FOR ";IY;"", MONTH ";IM;"", DAY ";ID;"", AT ";H;" HOURS"
890 E=FNDEG(H/100.)/24.-DT-LO/360.
900 D#=Z0#+E
910 N=1
920 GOSUB 1220
930 T=T+360.*E+LO
940 IF N=2 THEN GOSUB 1720
950 H=T-AS
960 GOSUB 2060
970 Z=H*DR
980 H=H-.95*(N-1)*COS(H*DR)
990 GOSUB 2160
1000 GOSUB 2200
1010 HA=INT(ABS(HA)+.5)*SGN(HA)
1020 ON N GOTO 1030,1090
1030 IS=133775.*M/SK
1040 PRINT"SUN AZIMUTH (DEG.) " ;AZ

```



```

1050 PRINT"SUN ALTITUDE (DEG.)      ";HA
1060 PRINT"SUN ILLUMINANCE (LUX)    ";IS
1070 N=2
1080 GOTO 940
1090 E=FNARCOS(COS(V-LS)*CB)
1100 P=.892*EXP(-3.343/((TAN(E/2.))^.632))+.0344*(SIN(E)-E*COS(E))
1110 P=.418*P/(1.-.005*COS(E)-.03*SIN(Z))
1120 IL=P*M/SK
1130 IS=IS+IL+.0005/SK
1140 PRINT"MOON AZIMUTH (DEG.)      ";AZ
1150 PRINT"MOON ALTITUDE (DEG.)     ";HA
1160 PRINT"MOON ILLUMINANCE (LUX)   ";IL
1170 IL=INT(50.*(1.-COS(E))+.5)
1180 PRINT" (";IL;"% OF MOON ILLUMINATED)"
1190 PRINT"TOTAL ILLUMINANCE (LUX)  ";IS
1200 GOTO 300
1210 END
1220 TD#=280.46#+.98565#*D#
1230 T=TD#-INT(TD#/360#)*360#
1240 IF T<0. THEN LET T=T+360.
1250 TD#=357.5#+.9856#*D#
1260 G=(TD#-INT(TD#/360#)*360#)*DR
1270 LS=(T+1.91*SIN(G))*DR
1280 AS=ATN(CE*TAN(LS))*RD
1290 Y=COS(LS)
1300 IF Y<0. THEN LET AS=AS+180.
1310 SD=SE*SIN(LS)
1320 DS=FNARCSIN(SD)
1330 T=T-180.
1340 RETURN
1350 R=M
1360 GOSUB 1700
1370 PRINT"SUN MERIDIAN PASSAGE AT ";R
1380 HA=INT(ABS(HA)+.5)*SGN(HA)
1390 PRINT"ALTITUDE AT MER. PASS.  ";HA
1400 FOR I=1 TO 2
1410 R=B(I)
1420 GOSUB 1700
1430 IF R>=4800. OR R<0. THEN GOTO 1680
1440 ON 2*(I-1)+I GOTO 1450,1470,1530,1550,1570,1590,1650,1670
1450 PRINT"TIME OF SUNRISE          ";R
1460 GOTO 1680
1470 PRINT"TIME OF SUNSET           ";R
1480 R=B(2)-B(1)
1490 IF R<0. THEN LET R=R+1.
1500 GOSUB 1700
1510 PRINT"TOTAL DAYLIGHT           ";R
1520 GOTO 1680
1530 PRINT"BEGIN CIVIL TWILIGHT AT ";R
1540 GOTO 1680
1550 PRINT"END CIVIL TWILIGHT AT    ";R
1560 GOTO 1680

```



```

1570 PRINT"BEGIN NAUTICAL TWILIGHT ";R
1580 GOTO 1680
1590 PRINT"END NAUTICAL TWILIGHT ";R
1600 GOTO 1680
1610 R=M
1620 GOSUB 1700
1630 PRINT"MOON MERIDIAN PASSAGE AT";R
1640 GOTO 1380
1650 PRINT"TIME OF MOONRISE ";R
1660 GOTO 1680
1670 PRINT"TIME OF MOONSET ";R
1680 NEXT I
1690 RETURN
1700 R=INT(100.*FNDMS(R*24.+.5))
1710 RETURN
1720 TD#=218.32#+13.1764#*D#
1730 V=TD#-INT(TD#/360#)*360#
1740 IF V<0. THEN LET V=V+360.
1750 TD#=134.96#+13.06499#*D#
1760 Y=(TD#-INT(TD#/360#)*360#)*DR
1770 TD#=93.27#+13.22935#*D#
1780 O=(TD#-INT(TD#/360#)*360#)*DR
1790 TD#=235.7#+24.3815#*D#
1800 W=(TD#-INT(TD#/360#)*360#)*DR
1810 SB=SIN(Y)
1820 CB=COS(Y)
1830 X=SIN(O)
1840 S=COS(O)
1850 SD=SIN(W)
1860 CD=COS(W)
1870 V=V+(6.29-1.27*CD+.43*CB)*SB+ (.66+1.27*CB)*SD-.19*SIN(G)-.23*X*S
1880 V=V*DR
1890 Y=(5.13-.17*CD)*X+(.56*SB+.17*SD)*S)*DR
1900 SV=SIN(V)
1910 SB=SIN(Y)
1920 CB=COS(Y)
1930 Q=CB*COS(V)
1940 P=CE*SV*CB-SE*SB
1950 SD=SE*SV*CB+CE*SB
1960 AS=ATN(P/Q)*RD
1970 IF Q<0. THEN LET AS=AS+180.
1980 DS=FNARCSIN(SD)
1990 RETURN
2000 H=(A(L)-SI*SD)/(CI*COS(DS))
2010 IF ABS(H)>1. THEN GOTO 2040
2020 H=FNARCOS(H)*RD/C
2030 RETURN
2040 H=1.5
2050 RETURN
2060 CD=COS(DS)
2070 CS=COS(H*DR)
2080 Q=SD*CI-CD*SI*CS

```



```

2090 P=-CD*SIN(H*DR)
2100 AZ=ATN(P/Q)*RD
2110 IF Q<0. THEN LET AZ=AZ+180.
2120 IF AZ<0. THEN LET AZ=AZ+360.
2130 AZ=INT(AZ+.5)
2140 H=FNARCSIN(SD*SI+CD*CI*CS)*RD
2150 RETURN
2160 HA=H
2170 IF H<(-5./6.) THEN GOTO 2190
2180 HA=H+1./(TAN((H+8.59/(H+4.42))*DR))/60.
2190 RETURN
2200 U=SIN(HA*DR)
2210 X=753.6616
2220 S=FNARCSIN(X*COS(HA*DR)/(X+1.))
2230 M=X*(COS(S)-U)+COS(S)
2240 M=EXP(-.21*M)*U+.0289*EXP(-.042*M)*(1.+(HA+90.)*U/57.29578)
2250 RETURN

```


The BASIC Routine for Programmable Calculator

This version of BASIC was written for a particular unit having a dual mode of operation -- one as a calculator with single keystroke trigonometric, power, root and other functions, the other as a computer having a BASIC interpreter resident in read-only-memory. The salient feature of a device of the type is a random-access-memory which retains programs when power is turned off. Coupled with small size and low cost, machines having these features may become attractive for many small scale computer needs and applications and, therefore, widely owned and used. There are limitations to this type of device too. Among them is the display, which holds only one line of prompt or output at one time; and that is further limited to relatively few characters. An attached printer would be more than a convenience.

Most of the comments applicable to the BASIC routine for personal computers apply to this routine also. The notes which follow supplement the general notes which begin this Section and those applicable to the routines for personal computers.

With the exception of one embedded subroutine, the main program begins at statement 10 and ends at statement 117. The remaining statements belong to the subroutines. The user may add code in statements 1 through 9, reserved for the purpose.

1. Precision

All scientific calculators routinely provide at least 8 to 10 digits of precision, so that consideration of extended or double precision code was unnecessary.

2. Changes to the program

Any changes required by syntax rules of various versions of BASIC must be accommodated. Some of these are discussed in the notes for the personal computer version.

If the DMS (convert to degrees, minutes, seconds) and DEG (convert to degrees and decimals) functions are not built in functions, they may be coded as user defined functions or as subroutines, according to the specific dialect available. If coded as subroutines, then statements 85 and 166 must be changed to GOSUB commands. If DMS and DEG are coded as user defined functions, then statement 85 may stand as it is. In the case of change to either subroutine or defined function form, the computation performed at statement 166 must be changed such that the constant .7 is replaced by .5. Statements which define the DMS and DEG functions are to be found on lines 30 and 40 of the personal computer version of the program, and should be keyed in to this version with line numbers less than 10.

Programmable calculators generally provide for recording programs so that they may be re-loaded without keying the instruction sequence. The user may find that a

label, title, or some other identification is then required at the head of the program. This may be added as statement number 1, if required.

At line 158 in the program is the single command BEEP. On some machines this produces audible tones. It was included at that point in the program to signal that a lengthy computation has been completed for the Moon; thus it allows the user to divert his attention for a time. The statement may be removed if the feature is not available or not wanted.

A printer connected to the calculator, or integrated, is a definite asset. The program may be modified to direct output to a printer by replacing all PRINT commands, (which usually only display output) if necessary, with whatever commands are necessary to produce actual printing. Examples include PRINT# and LPRINT. It may be possible, as an alternative, to issue a command which redefines the output device. One example of this is the statement PRINT=LPRINT which is required at some point in the program prior to the first PRINT command. It can be inserted in this program by assigning it using a line number less than 10. The user must not make any of the changes described before reading the requirements of the specific machine-interpreter configuration. The examples cited are not general or standard options.

Program execution may be re-directed to a limited degree. As provided here, the flow reflects certain ideas concerning probable usage. Other modes may be more convenient for some applications. Statement 82 may be altered to read GOTO 28, for entering a time of day. Statement 116 may be changed to read GOTO 18, for entering a new set of geographic coordinates and date. At least one of the statements should transfer to statement 18 for purposes of reinitializing.

3. Other changes

Relative to current programmable calculators, this is a large program. Changes other than those described in the preceding paragraph should be made with caution. Although some other changes could be made, it is possible that memory would be exceeded. Also, several variables are multiply-defined and certain computational sequences may not be disturbed or their results will be false. In the worst case, the end results (output) may appear reasonable.

4. Operation

Some devices are capable of operation with other than decimal numbers and, or, with angles in radians or grads. Decimal and degree modes must be specified before using this program.

Once the program has been implemented, operation should proceed interactively, with prompting by key words and phrases provided. Of necessity, abbreviations are used for prompting.

Figure 4 illustrates what is typically to be expected from the calculator version of the program. Two characteristics may be noted. For input to the program, no decimal points were used; the calculator is indifferent in this regard.

In the output, the times of events include decimal points, although not needed. The calculator assumes all numbers should have a decimal point. This should not trouble the user. The second characteristic is the appearance of a possibly unfamiliar notation for values of the illuminance. This form of writing a number is known as scientific notation, exponential form, or as power of 10 notation. The illuminance can vary through the course of a day by a *factor* of 100 million, yet calculated values may only contain one or two significant digits. Scientific notation is an appropriate way to represent the numbers and is, in fact, almost unavoidable. Any user who is unfamiliar with this notation can usually find it described fully in the literature which is supplied with the calculator.

```

LONG=- 77
LAT=39
YEAR=1986
MONTH=9
DAY=13
UT=0,STD=1,LMT=2
1
HOUR=1955
SKY=1,2,3,10?1
SUN AZ.      291.
SUN ALT. •   -19.
SUN ILL.     2.7E-06
MOON AZ.     169.
MOON ALT.    24.
MOON ILL2.0E-02
%MOON ILL.   79.
TOT. ILL     2.1E-02
HOUR=-3
SUN M.P.     1204.
ALT AT MP    55.
SUNRISE      547.
SUNSET       1820.
DAYLIGHT     1233.
BEG. C.T.    520.
END C.T.     1847.
BEG. N.T.    449.
END N.T.     1918.
MOON M.P.    2039.
ALT AT MP    25.
MOONRISE     1603.
MOONSET      8.

```

Figure 4 -- Interactive Input, Output (programmable calculator).

The BASIC Routine for Programmable Calculator

```
10 DIM A(4)
11 DIM B(2)
12 A(1)=-.01454
13 A(2)=-.10453
14 A(3)=-.20791
15 A(4)=.00233
16 CE=.91775
17 SE=.39715
18 INPUT "LONG=";LO,"LAT=";F,"YEAR=";Y,"MONTH=";M,"DAY=";D
19 C=360
20 L=ABS LO
21 SI=SIN F
22 CI=COS F
23 J=367*Y-INT(7*(Y+INT((M+9)/12))/4)+INT(275*M/9)+D-730531
24 INPUT "UT=0,STD=1,LMT=2",Z
25 DT=0
26 IF Z=0 LET DT=-LO/C
27 IF Z=1 LET DT=-(L-15*INT((L+7.5)/15))/C*SGN LO
28 INPUT "HOUR=";H
29 Z=J-.5
30 IF H>0 GOTO 83
31 FOR L=1 TO 4
32 ON L GOTO 34,61,61,33
33 C=347.81
34 M=.5+DT
35 FOR K=1 TO 6
36 M=M-DT
37 E=M-LO/360
38 GOSUB 40
39 GOTO 50
40 D=Z+E
41 IF ABS E >=1 LET E=E-SGN E
42 GOSUB 118
43 IF L=4 GOSUB 168
44 T=T+LO+360*E
45 T=T-INT(T/360)*360
46 U=T-AS
47 IF ABS U >180 LET U=U-360*SGN U
48 U=U/C
49 RETURN
50 M=M-U+DT
51 IF L<4 LET K=K+1
52 ON K GOTO 57,53,57,55,57,58
53 IF M>=0 AND M<1 GOTO 58
54 GOTO 56
55 IF M>=0 GOTO 58
56 M=M-SGN M
57 NEXT K
58 H=ASN(COS(F-DS))
59 IF L=4 LET H=H-.95*COS H
60 GOSUB 208
61 GOSUB 192
```



```

62 B(1)=M-H
63 B(2)=M+H
64 FOR I=1 TO 2
65 K=2*I-3
66 FOR N=1 TO 6
67 B(I)=B(I)-DT
68 E=B(I)-LO/360
69 GOSUB 40
70 GOSUB 192
71 B(I)=B(I)+K*H-U+DT
72 IF L<4 LET N=N+1
73 ON N GOTO 78,74,78,76,78,79
74 IF B(I)>=0 AND B(I)<1 GOTO 79
75 GOTO 77
76 IF B(I)>=0 GOTO 79
77 B(I)=B(I)-SGN B(I)
78 NEXT N
79 NEXT I
80 ON L GOSUB 130,135,135,156
81 NEXT L
82 GOTO 18
83 INPUT"SKY=1,2,3,10?";SK
84 PRINT"AT ";H;" HOURS"
85 E=DEG(H/100)/24-DT-LO/360
86 D=Z+E
87 N=1
88 GOSUB 118
89 T=T+360*E+LO
90 IF N=2 GOSUB 168
91 H=T-AS
92 GOSUB 198
93 Z=H
94 H=H-.95*(N-1)*COS H
95 GOSUB 208
96 GOSUB 212
97 HA=INT(ABS HA+.5)*SGN HA
98 ON N GOTO 99,105
99 I=133775.*M/SK
100 PRINT"SUN AZ.",AZ
101 PRINT"SUN ALT.",HA
102 PRINT"SUN ILL.",I
103 N=2
104 GOTO 90
105 E=ACS(COS(V-LS)*CB)
106 P=.892*EXP(-3.343/((TAN(E/2))^1.632))+.0344*(SIN E-E/57.29578*COSE)
107 P=.418*P/(1-.005*COS E-.03*SIN Z )
108 L=P*M/SK
109 I=I+L+.0005/SK
110 PRINT"MOON AZ.",AZ
111 PRINT"MOON ALT.",HA
112 PRINT"MOON ILL.",L
113 L=INT(50*(1-COS E)+.5)

```



```

114 PRINT"% MOON ILL.",L
115 PRINT"TOT.ILL.",I
116 GOTO 28
117 END
118 T=280.46+.98565*D
119 T=T-INT(T/360)*360
120 IF T<0 LET T=T+360
121 G=SIN(357.5+.9856*D)
122 LS=T+1.91*G
123 AS=ATN(CE*TAN LS)
124 Y=COS LS
125 IF Y<0 LET AS=AS+180
126 SD=SE*SIN LS
127 DS=ASN SD
128 T=T-180
129 RETURN
130 R=M
131 GOSUB 166
132 PRINT"SUN M.P.",R
133 HA=INT(ABS HA+.5)*SGN HA
134 PRINT"ALT AT MP",HA
135 FOR I=1 TO 2
136 R=B(I)
137 GOSUB 166
138 IF R>=4800 OR R<0 GOTO 164
139 ON 2*(L-1)+I GOTO 140,142,148,150,152,154,161,163
140 PRINT"SUNRISE",R
141 GOTO 164
142 PRINT"SUNSET",R
143 R=B(2)-B(1)
144 IF R<0 LET R=R+1
145 GOSUB 166
146 PRINT"DAYLIGHT",R
147 GOTO 164
148 PRINT"BEG. C.T.",R
149 GOTO 164
150 PRINT"END C.T.",R
151 GOTO 164
152 PRINT"BEG. N.T.",R
153 GOTO 164
154 PRINT"END N.T.",R
155 GOTO 164
156 R=M
157 GOSUB 166
158 BEEP 3
159 PRINT"MOON M.P.",R
160 GOTO 133
161 PRINT"MOONRISE",R
162 GOTO 164
163 PRINT"MOONSET",R
164 NEXT I
165 RETURN

```



```

166 R=INT(100*DMS(R*24)+.7)
167 RETURN
168 V=218.32+13.1764*D
169 V=V-INT(V/360)*360
170 IF V<0 LET V=V+360
171 Y=134.96+13.06499*D
172 O=93.27+13.22935*D
173 W=235.7+24.3815*D
174 SB=SIN Y
175 CB=COS Y
176 X=SIN O
177 S=COS O
178 SD=SIN W
179 CD=COS W
180 V=V+(6.29-1.27*CD+.43*CB)*SB+(.66+1.27*CB)*SD-.19*G-.23*X*S
181 Y=(5.13-.17*CD)*X+(.56*SB+.17*SD)*S
182 SV=SIN V
183 SB=SIN Y
184 CB=COS Y
185 Q=CB*COS V
186 P=CE*SV*CB-SE*SB
187 SD=SE*SV*CB+CE*SB
188 AS=ATN(P/Q)
189 IF Q<0 LET AS=AS+180
190 DS=ASN SD
191 RETURN
192 H=(A(L)-SI*SD)/(CI*COS DS)
193 IF ABS H>1 GOTO 196
194 H=(ACS H)/C
195 RETURN
196 H=1.5
197 RETURN
198 CD=COS DS
199 CS=COS H
200 Q=SD*CI-CD*SI*CS
201 P=-CD*SIN H
202 AZ=ATN(P/Q)
203 IF Q<0 LET AZ=AZ+180
204 IF AZ<0 LET AZ=AZ+360
205 AZ=INT(AZ+.5)
206 H=ASN(SD*SI+CD*CI*CS)
207 RETURN
208 HA=H
209 IF H<(-5/6) GOTO 211
210 HA=H+1/(TAN(H+8.6/(H+4.42)))/60
211 RETURN
212 U=SIN HA
213 X=753.66156
214 S=ASN (X*COS(HA)/(X+1))
215 M=X*(COS S-U)+COS S
216 M=EXP(-.21*M)*U+.0289*EXP(-.042*M)*(1+(HA+90)*U/57.29578)
217 RETURN

```


SECTION III

Contingent Tables and Diagrams

As the heading suggests, the tables and diagrams are for use when a computing device is not available. For the Sun, all of the data provided by the computer routines are also available from the tables and diagrams. Tables required for manual calculation of the Moon's positions and phenomena are not provided, since they would be numerous and complex. Graphs of lunar illuminance are included should the altitude and phase be available from other sources. Otherwise, the graphs will provide only an indication of available moonlight, based on whatever information concerning Moon visibility is at hand.

The terminology and descriptions found in Section I are relevant to the methods described in this section and are not repeated. Declination is a term not described in Section I. It is one of the coordinates used to specify the position of an object on the celestial sphere, in a manner analogous to latitude on the Earth. Since the Sun's declination is used here only to determine other quantities, it can be considered as an intermediate quantity, and a full description or visualization of it is not strictly necessary.

These tables and diagrams are not new; variations have appeared in handbooks and other literature in the past. Many of those publications are no longer available. Moreover, many were less extensive and more complicated to use correctly. These tables and diagrams are complete and, it is hoped, more direct. Nevertheless, at extreme latitudes, it is to be expected that they will produce times of rising, setting and twilight which may compare poorly to more refined calculations and to the times of the actual events. The altitude, azimuth diagrams for such latitudes demonstrate that the Sun's path will approach and cross the horizon slowly and at shallow angles during certain times of the year. Meteorological conditions, rarely nominal in those regions, cause wide variations in refraction, which in turn combines almost directly with the geometry of the situation to produce significant differences between calculated and observed events.

Description of the tables and diagrams:

Table 1 -- Sun Meridian Passage Increment and Declination: For each day of the year, the table provides an adjustment (MP) which must be applied to Noon and to all other event times to express them in Local Mean Time. It also gives the Sun's declination, for the date, which is required for the use of Table 2 or the altitude, azimuth diagrams. The meridian passage increment is given to the nearest minute and the Sun's declination to the nearest half-degree. The fractional degree is provided for estimating times halfway between those given by Table 2, should the

user desire. Ordinarily this will not be required. (At latitudes where the Sun will rise or set and then remain above or below the horizon for long periods, the declination column for Table 2 provides for direct entry to the nearest half-degree). Following Table 1 are graphs showing MP and DEC which may be used in place of Table 1, if desired.

Table 2: For the latitude of the location of interest, and for the Sun's declination from Table 1, Table 2 immediately provides the altitude of the Sun above the horizon when it crosses the meridian (AL) and the length of the day (LD) from sunrise to sunset. Table 2 also yields three quantities which are the core times for the calculation of sunrise, sunset (R/S), and civil (CT) and nautical (NT) twilight. The interval of latitude between 0 and 82 degrees is one degree throughout. Declination is generally at a one degree interval, but there are exceptions. The maximum solar declination is about 23.5 degrees and that value is tabulated on every page of the table. Half-degree values of solar declination near the condition which produces periods of continuous sunlight or darkness are also included.

Table 3 -- Longitude, Time Adjustments: This table, entered with longitude, provides adjustments which convert Local Mean Time to Universal Time (UT) or to Zone Time (ZC), or conversely. The interval of longitude is one degree which corresponds to the UT and ZC intervals of four minutes. The table may be interpolated visually for fractions of a degree of longitude corresponding to the nearest minute of time, if desired. In applying the adjustment from Mean Time to Zone Time, if Daylight (Summer) Time is in effect, or if the legal time of a place is not within the boundaries of the uniform system, the table may still be used with an additional hour added or subtracted afterward, as dictated by the circumstances.

Altitude, Azimuth Diagrams: These are 33 diagrams which transform a time of day and solar declination into altitude and azimuth referred to the geographic position of interest. The diagrams are drawn for whole multiples of five degrees of latitude and marked with offsets which make them useful for any latitude, from the equator to 82 degrees North and South. Cardinal directions are indicated. On the diagrams, lines extending North to South (the meridian) are intersected by lines from East to West at the origin, which point corresponds to the latitude printed at the top of the page in large type. Above and below the origin are short line segments representing one and two degrees of latitude greater or less than that for which the figure was drawn. These are used to reckon altitudes and azimuths for latitudes which are not multiples of five degrees. Azimuth is indicated for every two degrees at the edge of the diagrams, but one degree resolution is easily achieved by eye. The outermost circle (boundary) represents an altitude of six degrees below the horizon and corresponds to civil twilight. The horizon circle is drawn inside the twilight circle. On each diagram, there are curves representing the path of the Sun from morning civil twilight through rise, meridian passage and set, to evening civil twilight. The interval between these paths is two degrees of

solar declination except for the limiting values of 23.5 degrees, which are also shown. Curves representing every 10 degrees of declination are accented and labelled. Time lines drawn at 10 minute intervals, with each hour accented, intersect the declination curves. The time lines are labelled at an hourly interval but, with the exception of the Noon line, only with two digits. At the foot of each diagram is an altitude scale.

When the Sun is nearly overhead, at a specific location, the azimuth is poorly determined by the diagrams. This approximates the real situation of indeterminate azimuth when the Sun is in the zenith.

The diagrams can also be used inversely to obtain times and dates when the Sun is at specific altitudes or azimuths.

Solar Illuminance Diagram: This single diagram gives the illuminance by the Sun on a horizontal surface as a function of altitude. The scale of illuminance is logarithmic. The altitude scale is expanded for solar altitude less than +10 deg., since the change in illuminance with altitude is greatest when the Sun is near the horizon. Above 10 deg. altitude the change in illuminance is less dramatic, as far as vision is concerned, and the exact amount of illuminance is less important for practical concerns. Four curves are shown in the diagram. Each corresponds to a sky condition, or factor, described in Section I and is indicated by the letter F with numerical suffix to the right of the diagram.

Lunar Illuminance Diagrams: Four diagrams are provided, each corresponding to a condition of the sky as described in Section I. Each diagram shows illuminance on a horizontal surface as a function of altitude. But the illuminance by the Moon also depends upon its phase. Phase is a continuous function of the angular separation of the Moon from the Sun (elongation), and for quantitative purposes it is better represented by the percent of the Moon illuminated than by the traditional, restrictive terms Quarter, Full, etc. At the right of each diagram, therefore, the illuminance curves are designated by percent illuminated and by corresponding values of the elongation. Values of the percent of the Moon illuminated must be taken from other sources. *The Air Almanac*, for example, gives the quantity in tabular format at semi-daily interval.

Figure 5 shows an altitude, azimuth diagram for an actual location which has an obstructed horizon. The shaded area was determined by crude measurements of altitudes and azimuths of the obstructions which included trees and buildings on rolling landscape. For example, the spike at azimuth 155 deg. is a tower supporting environmental sensors; at azimuth 350 deg. is a church tower. The profile of the shaded area was faired by hand, since the particular application of the diagram was not critical. The shading suggests collateral uses for the diagrams, as well as the obvious applications in which the availability of direct sunlight is a factor. It should also amplify the significance of the assumptions made in determining illuminance by calculation or graphically. In Figure 5, for example, it is seen that when the Sun's azimuth is greater than 212 deg. while its

altitude is less than 12 deg., there is no direct sunlight. The actual illuminance would be considerably less than predicted, for the circumstances. Also, less (indirect) skylight would be available at any time, since not all of the sky is visible at the location. On the other hand, both natural and manmade obstructions reflect various amounts of incident light, so that it is not generally possible to estimate the attenuated light level from the geometry of the figure only. The safe interpretation of illuminance figures, therefore, is to postulate that they are the maximum possible amounts. This may be adequate to determine whether certain activities are possible without artificial lighting or aided vision.

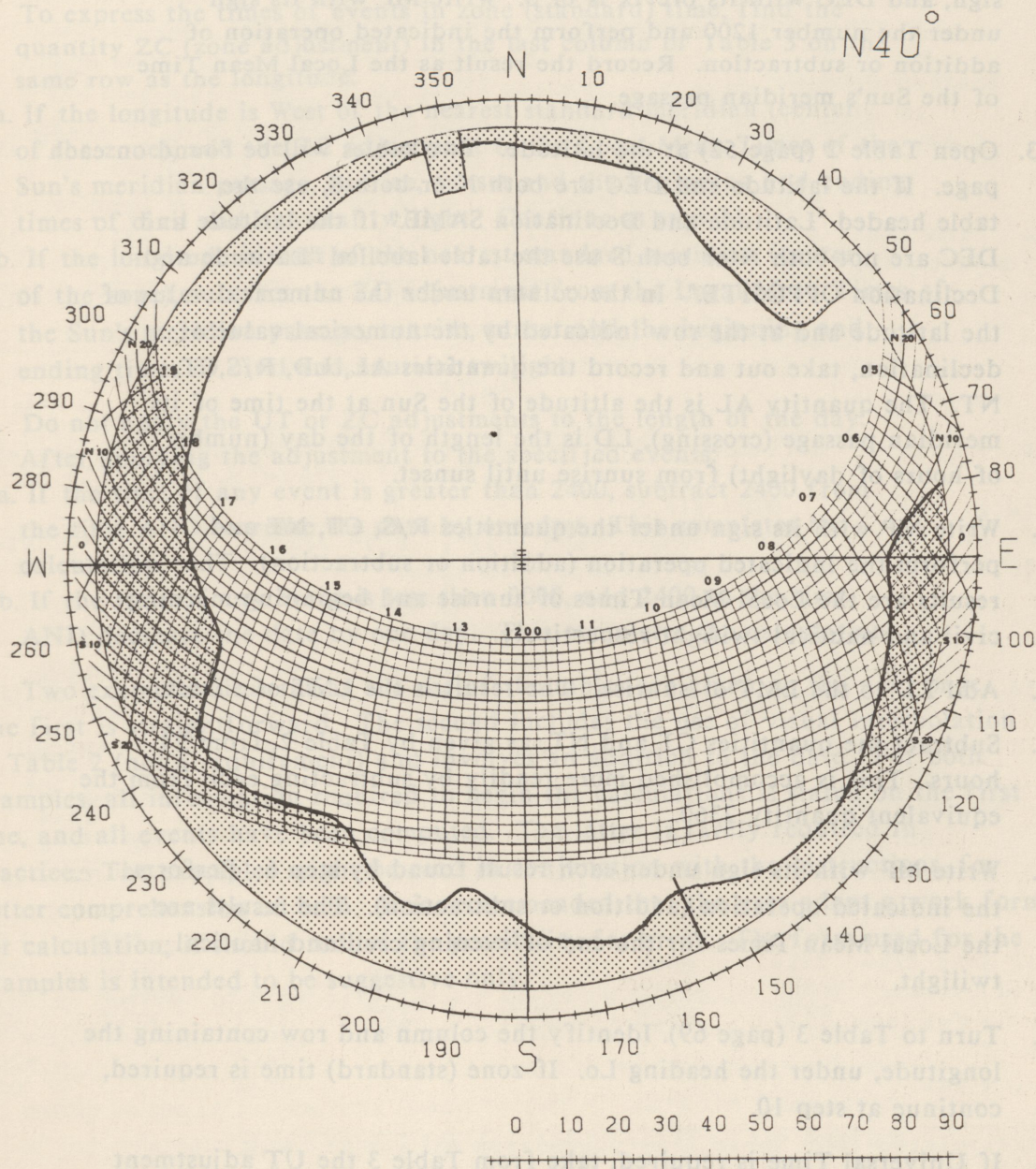


Figure 5 -- Altitude, Azimuth Diagram showing obstructed horizon.

Instructions for calculation of events using the tables:

1. Obtain and record the geographic coordinates to the nearest degree of latitude and longitude for the location of interest. Label the latitude with N or S according to whether the location is North or South of the equator. Label the longitude E or W according to whether the location is East or West of the prime meridian.
2. Enter Table 1 (page 50) at the month (column) and day of the month (row). Take out the quantity MP with its positive (+) or negative (-) sign, and DEC with its prefix N or S. Write MP with its sign under the number 1200 and perform the indicated operation of addition or subtraction. Record the result as the Local Mean Time of the Sun's meridian passage.
3. Open Table 2 (page 52) at the latitude. Two tables will be found on each page. If the latitude and DEC are both N or both S, use the table headed "Latitude and Declination SAME." If the latitude and DEC are not both N or both S use the table labelled "Latitude and Declination OPPOSITE." In the column under the numerical value of the latitude and at the row indicated by the numerical value of declination, take out and record the quantities AL, LD, R/S, CT, NT. The quantity AL is the altitude of the Sun at the time of its meridian passage (crossing), LD is the length of the day (number of hours of daylight) from sunrise until sunset.
4. Write MP with its sign under the quantities R/S, CT, NT and perform the indicated operation (addition or subtraction). The results are the Local Mean Times of sunrise and beginning morning civil and nautical twilight respectively.
5. Add LD to the LMT of sunrise. The result is the LMT of sunset.
6. Subtract the quantities CT and NT, as given by Table 2, from 24 hours. This is accomplished more readily by subtracting each from the equivalent quantity 2360.
7. Write MP with its sign under each result found by step 6. Perform the indicated operation (addition or subtraction). The results are the Local Mean Times for the end of evening civil and nautical twilight.
8. Turn to Table 3 (page 69). Identify the column and row containing the longitude, under the heading Lo. If zone (standard) time is required, continue at step 10.
9. If Universal Time is required, take from Table 3 the UT adjustment found in the same column at the same row as the longitude.

- 9a. If the longitude is West (W) of the prime meridian, add the UT adjustment to the Local Mean Times of the Sun's meridian passage, sunrise, sunset and the beginning and ending times of civil and nautical twilight. The events are now expressed in Universal Time. Continue at step 11.
- 9b. If the longitude is East (E) of the prime meridian, subtract the UT adjustment from the Local Mean Times of the Sun's meridian passage, sunrise, sunset and the beginning and ending times of civil and nautical twilight. The events are now expressed in Universal Time. Continue at step 11.
10. To express the times of events in zone (standard) time, find the quantity ZC (zone adjustment) in the last column of Table 3 on the same row as the longitude.
- 10a. If the longitude is West of the nearest standard meridian (center of the zone), add the ZC adjustment to the Local Mean Times of the Sun's meridian passage, sunrise, sunset and the beginning and ending times of civil and nautical twilight. Continue at step 11.
- 10b. If the longitude is East of the nearest standard meridian (center of the zone), subtract the ZC adjustment from the Local Mean Times of the Sun's meridian passage, sunrise, sunset and the beginning and ending times of civil and nautical twilight.
11. Do not apply the UT or ZC adjustments to the length of the day. After applying the adjustment to the specified events:
 - 11a. If the time of any event is greater than 2400, subtract 2400 from the time AND increase the date by one day. This completes the calculation.
 - 11b. If the time of any event is less than 0000, add 2400 to the time AND decrease the date by one day. This completes the calculation.

Two examples illustrating the use of the tables are given on the next page. The first is straightforward. The second includes the use of visual interpolation in Table 2 (not a requirement) and involves an addition to the date. For both examples, all information required to begin the calculations is stated on the first line, and all events have been computed. The latter is rarely required in practice. The examples might be read in conjunction with the instructions, for better comprehension of both. It is recommended that the user adopt a work form for calculation; it should reduce the possibility for error. The form used for the examples is intended to be suggestive only.

EXAMPLE 1

Date: 17 Nov., Latitude: N13, Longitude: E145, Event Times: Zone

Table 1: MP= -15 DEC= S19

Table 2: (OPPOSITE), AL= 58deg., LD= 1131, R/S= 0615, CT= 0552, NT= 0526

Table 3: (Zone Time adjustment to 150th meridian) ZC= 20

1200	CT 0552	NT 0526				
MP <u>-15</u>	MP <u>-15</u>	MP <u>-15</u>				
Merid. Pass. <u>1145</u> LMT	Beg. Civ. Twi. <u>0537</u> LMT	Beg. Naut. Twi. <u>0511</u> LMT				
R/S 0615	(24 hours) 2360	(24 hours) 2360				
MP <u>-15</u>	CT <u>-0552</u>	NT <u>-0526</u>				
Sunrise <u>0600</u> LMT	1808	1834				
LD <u>1131</u>	MP <u>-15</u>	MP <u>-15</u>				
Sunset <u>1731</u> LMT	End Civ. Twi. <u>1753</u> LMT	End Naut. Twi. <u>1819</u> LMT				
M.P.	Rise	Set	BCT	ECT	BNT	ENT
Local Mean Time 1145	0600	1731	0537	1753	0511	1819
ZC (adjustment) <u>+20</u>	<u>+20</u>	<u>+20</u>	<u>+20</u>	<u>+20</u>	<u>+20</u>	<u>+20</u>
Zone time 1205	0620	1751	0557	1813	0531	1839

EXAMPLE 2

Date: 3 Feb., Latitude: S59, Longitude: W55, Event Times: Universal

Table 1: MP= +14, DEC= S16.5

Table 2: (SAME), AL=47.5*deg., LD= 1612*, R/S= 0354*, CT= 0300*, NT=0136*

Table 3: (Universal Time adjustment) UT= 0340

1200	CT 0300*	NT 0136*				
MP <u>+14</u>	MP <u>+14</u>	MP <u>+14</u>				
Merid. Pass. 1214 LMT	Beg. Civ. Twi. 0314 LMT	Beg. Naut. Twi. 0150 LMT				
R/S 0354*	(24 hours) 2360	(24 hours) 2360				
MP <u>+14</u>	CT <u>-0300*</u>	NT <u>-0136*</u>				
Sunrise 0408 LMT	2100	2224				
LD <u>1612*</u>	MP <u>+14</u>	MP <u>+14</u>				
Sunset 2020 LMT	End Civ. Twi. 2114 LMT	End Naut. Twi. 2238 LMT				
M.P.	Rise	Set	BCT	ECT	BNT	ENT
Local Mean Time 1214	0408	2020	0314	2114	0150	2238
UT (adjustment) <u>+0340</u>	<u>+0340</u>	<u>+0340</u>	<u>+0340</u>	<u>+0340</u>	<u>+0340</u>	<u>+0340</u>
U.T., 3 Feb. 1554	0748	2400	0654	2454	0530	2618
				<u>-2400</u>		<u>-2400</u>
U.T., 4 Feb.				0054		0218

* Interpolated from Table 2 by inspection with DEC= 16.5.

Instructions for calculation of the Sun's altitude, azimuth and illuminance:

1. Obtain and record the geographic coordinates to the nearest degree of latitude and longitude for the location of interest. Label the latitude with N or S according to whether the location is in the northern or southern hemisphere. Label the longitude E or W according to whether the location is East or West of the prime meridian.
2. Enter Table 3 (page 69). Identify the column and row containing the longitude, under the heading Lo. If the time of day is given in Zone (Standard) Time, proceed at Step 3. If the time of day is given in Universal Time, take from Table 3 the UT adjustment found in the same column at the same row as the longitude.
 - 2a. If the longitude is West of the prime meridian, subtract the UT adjustment from the given time of day. Continue at step 4.
 - 2b. If the longitude is East of the prime meridian, add the UT adjustment to the given time of day. Continue at step 4.
3. To convert Zone Time, find the ZC adjustment in the last column of Table 3 on the same row as the longitude.
 - 3a. If the longitude is West of the nearest standard meridian, subtract the ZC adjustment from the given time of day. Continue at step 4.
 - 3b. If the longitude is East of the nearest standard meridian, add the ZC adjustment to the given time of day.
4. Enter Table 1 (page 50) with the month (column) and day of the month (row). Take out the MP increment and write it under the Local Mean Time found by step 2 or step 3 but with its sign changed (plus to minus or minus to plus), unless the value of MP is zero. Perform the indicated operation of combining MP with LMT to produce the reference times for the altitude, azimuth diagram. Also take the declination of the Sun (DEC) from Table 1.
5. Determine which multiple of five degrees, North or South, is nearest to the given latitude and open the diagram pages (page 70) at that latitude. To prevent deterioration through repeated use, working copies of the page should be made so that notes and azimuth (bearing) lines can be placed on the copies.
6. Near the edge of the diagram locate the Sun's declination curve which corresponds most nearly to the value of DEC taken from Table 1. Follow the declination curve to the time line which corresponds most nearly to the reference time found by step 4. Mark the intersection of the reference time line and the declination curve on the diagram.

7. Locate the origin for the given latitude on the diagram. If the given latitude is one or two degrees South of the latitude for which the diagram is drawn, the offset origin will be found at the first or second line segment below the East-West line. If the given latitude is one or two degrees North of the diagram latitude, the offset origin will be at the first or second line segment above the East-West line.
8. Place a ruler or straightedge on the diagram in such a way as to connect the latitude origin and the Sun's position determined in step 6. The straightedge or ruler should then intersect the graduated outer circle of the diagram where the azimuth is read immediately.
9. Mark the straightedge or ruler where it meets the origin for the given latitude and where it meets the Sun's indicated position (step 6). Place the straightedge parallel to the altitude scale at the bottom of the diagram so that one of the marks coincides with the point designated 90. The other mark then gives the point on the scale at which the Sun's altitude is read. Dividers may also be used to find the altitude.
10. Referring to the Solar Illuminance Diagram (page 103), locate the Sun's altitude, found above, on the horizontal scale. The appropriate illuminance curve is selected by estimating the cloud cover according to the criteria given in Section 1. The illuminance is then read from the vertical scale of the diagram.

Two examples are given to illustrate the use of an altitude, azimuth diagram, both for the location 37 deg. North and 122 deg. West, under clear skies.

Example 3: To find the azimuth, altitude and solar illuminance on 15 March at 0927 (Pacific) Standard Time.

Example 4: To find the azimuth, altitude and solar illuminance on 6 October at 0121 Universal Time.

The calculations and results are summarized on the next page, which also shows the corresponding diagram with azimuth lines drawn. Example 3 is a straightforward application of the instructions. In plotting the position of the Sun for Example 4 however, the declination and reference time indicate a point midway between grid lines, and visual interpolation was used to locate the point. Also, it should be noted that, for the given longitude, the conversion from Universal to Local Mean Time necessitates a change to the date.

EXAMPLE 3

Date: 15 Mar., Lat: N37, Long: W122

Sky: clear

Table 3: (Zone Time) ZC= 08

Table 1: MP= +09; DEC= S 2

Zone Time 0927

ZC (adjustment) -08

LMT 0919

MP (opposite sign) -09

Reference time 0910 (for diagram)

Diagram: Azimuth = 124 deg.

Altitude = +34 deg.

Graph: (F1) Illuminance = 60,000 lux

EXAMPLE 4

Date: 6 Oct., Lat: N37, Long: W122

Sky: clear

Table 3: (Universal Time) UT= 0808

Table 1: MP= -12, DEC= S 5

Universal Time 0121

UT (adjustment) -0808

5 Oct., LMT 1713

MP (opposite sign) +12

Reference time 1725 (for diagram)

Diagram: Azimuth = 260 deg.

Altitude = + 4 deg.

Graph: (F1) Illuminance = 4000 lux

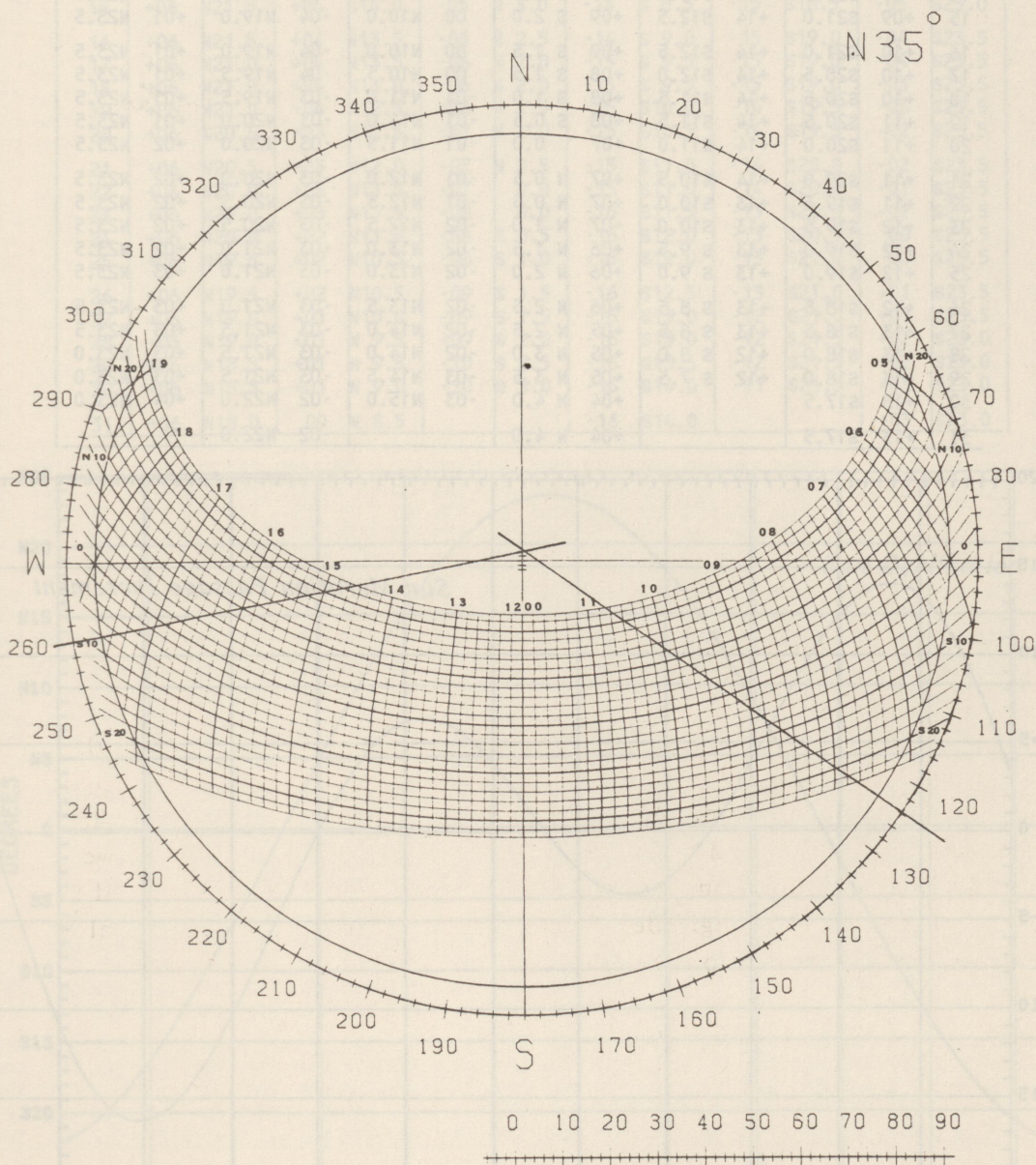


Table 1 -- Sun Meridian Passage Increment and Declination

DAY	Jan.		Feb.		Mar.		Apr.		May		June	
	MP	DEC	MP	DEC	MP	DEC	MP	DEC	MP	DEC	MP	DEC
	m	o	m	o	m	o	m	o	m	o	m	o
1	+03	S23.0	+13	S17.0	+12	S 7.5	+04	N 4.5	-03	N15.0	-02	N22.0
2	+04	S23.0	+14	S17.0	+12	S 7.0	+04	N 5.0	-03	N15.5	-02	N22.0
3	+04	S23.0	+14	S16.5	+12	S 6.5	+03	N 5.5	-03	N15.5	-02	N22.5
4	+05	S22.5	+14	S16.0	+12	S 6.5	+03	N 6.0	-03	N16.0	-02	N22.5
5	+05	S22.5	+14	S16.0	+11	S 6.0	+03	N 6.0	-03	N16.5	-01	N22.5
6	+06	S22.5	+14	S15.5	+11	S 5.5	+02	N 6.5	-03	N16.5	-01	N22.5
7	+06	S22.5	+14	S15.5	+11	S 5.0	+02	N 7.0	-03	N17.0	-01	N22.5
8	+07	S22.0	+14	S15.0	+11	S 5.0	+02	N 7.5	-03	N17.0	-01	N23.0
9	+07	S22.0	+14	S14.5	+10	S 4.5	+02	N 7.5	-03	N17.5	-01	N23.0
10	+07	S22.0	+14	S14.5	+10	S 4.0	+01	N 8.0	-04	N17.5	-01	N23.0
11	+08	S22.0	+14	S14.0	+10	S 3.5	+01	N 8.5	-04	N18.0	00	N23.0
12	+08	S21.5	+14	S13.5	+10	S 3.0	+01	N 8.5	-04	N18.0	00	N23.0
13	+09	S21.5	+14	S13.5	+09	S 3.0	+01	N 9.0	-04	N18.5	00	N23.0
14	+09	S21.5	+14	S13.0	+09	S 2.5	00	N 9.5	-04	N18.5	00	N23.0
15	+09	S21.0	+14	S12.5	+09	S 2.0	00	N10.0	-04	N19.0	+01	N23.5
16	+10	S21.0	+14	S12.5	+09	S 1.5	00	N10.0	-04	N19.0	+01	N23.5
17	+10	S20.5	+14	S12.0	+08	S 1.5	00	N10.5	-04	N19.5	+01	N23.5
18	+10	S20.5	+14	S11.5	+08	S 1.0	-01	N11.0	-03	N19.5	+01	N23.5
19	+11	S20.5	+14	S11.5	+08	S 0.5	-01	N11.0	-03	N20.0	+01	N23.5
20	+11	S20.0	+14	S11.0	+07	S 0.0	-01	N11.5	-03	N20.0	+02	N23.5
21	+11	S20.0	+14	S10.5	+07	N 0.5	-01	N12.0	-03	N20.0	+02	N23.5
22	+11	S19.5	+13	S10.0	+07	N 0.5	-01	N12.5	-03	N20.5	+02	N23.5
23	+12	S19.5	+13	S10.0	+07	N 1.0	-02	N12.5	-03	N20.5	+02	N23.5
24	+12	S19.0	+13	S 9.5	+06	N 1.5	-02	N13.0	-03	N21.0	+02	N23.5
25	+12	S19.0	+13	S 9.0	+06	N 2.0	-02	N13.0	-03	N21.0	+03	N23.5
26	+12	S18.5	+13	S 8.5	+06	N 2.5	-02	N13.5	-03	N21.0	+03	N23.5
27	+13	S18.5	+13	S 8.5	+05	N 2.5	-02	N14.0	-03	N21.5	+03	N23.5
28	+13	S18.0	+12	S 8.0	+05	N 3.0	-02	N14.0	-03	N21.5	+03	N23.0
29	+13	S18.0	+12	S 7.5	+05	N 3.5	-03	N14.5	-03	N21.5	+03	N23.0
30	+13	S17.5			+04	N 4.0	-03	N15.0	-02	N22.0	+04	N23.0
31	+13	S17.5			+04	N 4.0			-02	N22.0		

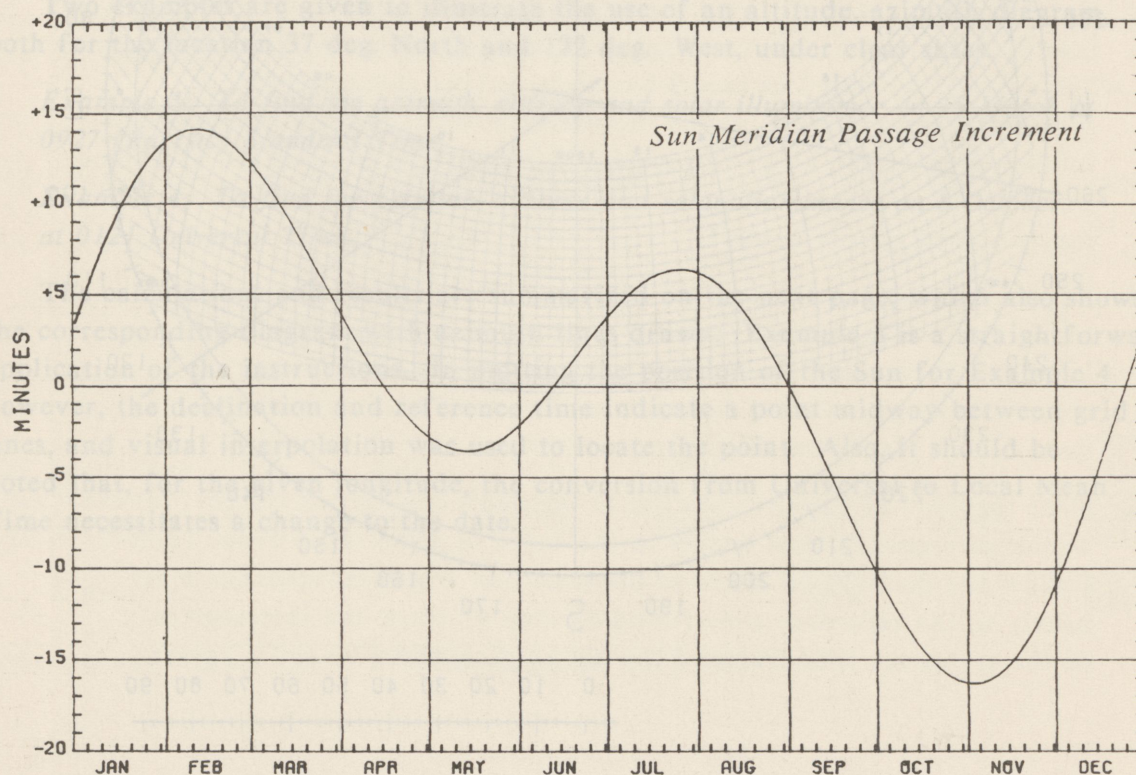


Table 1 -- Sun Meridian Passage Increment and Declination

DAY	July		Aug.		Sep.		Oct.		Nov.		Dec.	
	MP	DEC	MP	DEC	MP	DEC	MP	DEC	MP	DEC	MP	DEC
	m	o	m	o	m	o	m	o	m	o	m	o
1	+04	N23.0	+06	N18.0	00	N 8.0	-10	S 3.5	-16	S14.5	-11	S22.0
2	+04	N23.0	+06	N17.5	00	N 8.0	-11	S 3.5	-16	S15.0	-10	S22.0
3	+04	N23.0	+06	N17.5	-01	N 7.5	-11	S 4.0	-16	S15.0	-10	S22.0
4	+04	N23.0	+06	N17.0	-01	N 7.0	-11	S 4.5	-16	S15.5	-10	S22.0
5	+05	N22.5	+06	N17.0	-01	N 6.5	-12	S 5.0	-16	S15.5	-09	S22.5
6	+05	N22.5	+06	N16.5	-02	N 6.5	-12	S 5.0	-16	S16.0	-09	S22.5
7	+05	N22.5	+06	N16.5	-02	N 6.0	-12	S 5.5	-16	S16.5	-08	S22.5
8	+05	N22.5	+06	N16.0	-02	N 5.5	-12	S 6.0	-16	S16.5	-08	S22.5
9	+05	N22.5	+05	N16.0	-03	N 5.0	-13	S 6.5	-16	S17.0	-08	S23.0
10	+05	N22.0	+05	N15.5	-03	N 5.0	-13	S 6.5	-16	S17.0	-07	S23.0
11	+05	N22.0	+05	N15.0	-03	N 4.5	-13	S 7.0	-16	S17.5	-07	S23.0
12	+06	N22.0	+05	N15.0	-04	N 4.0	-13	S 7.5	-16	S17.5	-06	S23.0
13	+06	N22.0	+05	N14.5	-04	N 3.5	-14	S 8.0	-16	S18.0	-06	S23.0
14	+06	N21.5	+05	N14.5	-04	N 3.5	-14	S 8.0	-15	S18.5	-05	S23.0
15	+06	N21.5	+04	N14.0	-05	N 3.0	-14	S 8.5	-15	S18.5	-05	S23.0
16	+06	N21.5	+04	N13.5	-05	N 2.5	-14	S 9.0	-15	S19.0	-04	S23.5
17	+06	N21.0	+04	N13.5	-06	N 2.0	-15	S 9.5	-15	S19.0	-04	S23.5
18	+06	N21.0	+04	N13.0	-06	N 2.0	-15	S 9.5	-15	S19.0	-03	S23.5
19	+06	N21.0	+04	N12.5	-06	N 1.5	-15	S10.0	-14	S19.5	-03	S23.5
20	+06	N20.5	+03	N12.5	-07	N 1.0	-15	S10.5	-14	S19.5	-02	S23.5
21	+06	N20.5	+03	N12.0	-07	N 0.5	-15	S11.0	-14	S20.0	-02	S23.5
22	+06	N20.0	+03	N11.5	-07	0.0	-15	S11.0	-14	S20.0	-01	S23.5
23	+06	N20.0	+03	N11.5	-08	0.0	-16	S11.5	-13	S20.5	-01	S23.5
24	+06	N20.0	+02	N11.0	-08	S 0.5	-16	S12.0	-13	S20.5	00	S23.5
25	+06	N19.5	+02	N10.5	-08	S 1.0	-16	S12.0	-13	S21.0	00	S23.5
26	+06	N19.5	+02	N10.5	-09	S 1.5	-16	S12.5	-13	S21.0	+01	S23.5
27	+06	N19.0	+01	N10.0	-09	S 1.5	-16	S13.0	-12	S21.0	+01	S23.5
28	+06	N19.0	+01	N 9.5	-09	S 2.0	-16	S13.0	-12	S21.5	+02	S23.0
29	+06	N18.5	+01	N 9.5	-10	S 2.5	-16	S13.5	-12	S21.5	+02	S23.0
30	+06	N18.5	+01	N 9.0	-10	S 3.0	-16	S14.0	-11	S21.5	+03	S23.0
31	+06	N18.0	00	N 8.5			-16	S14.0			+03	S23.0

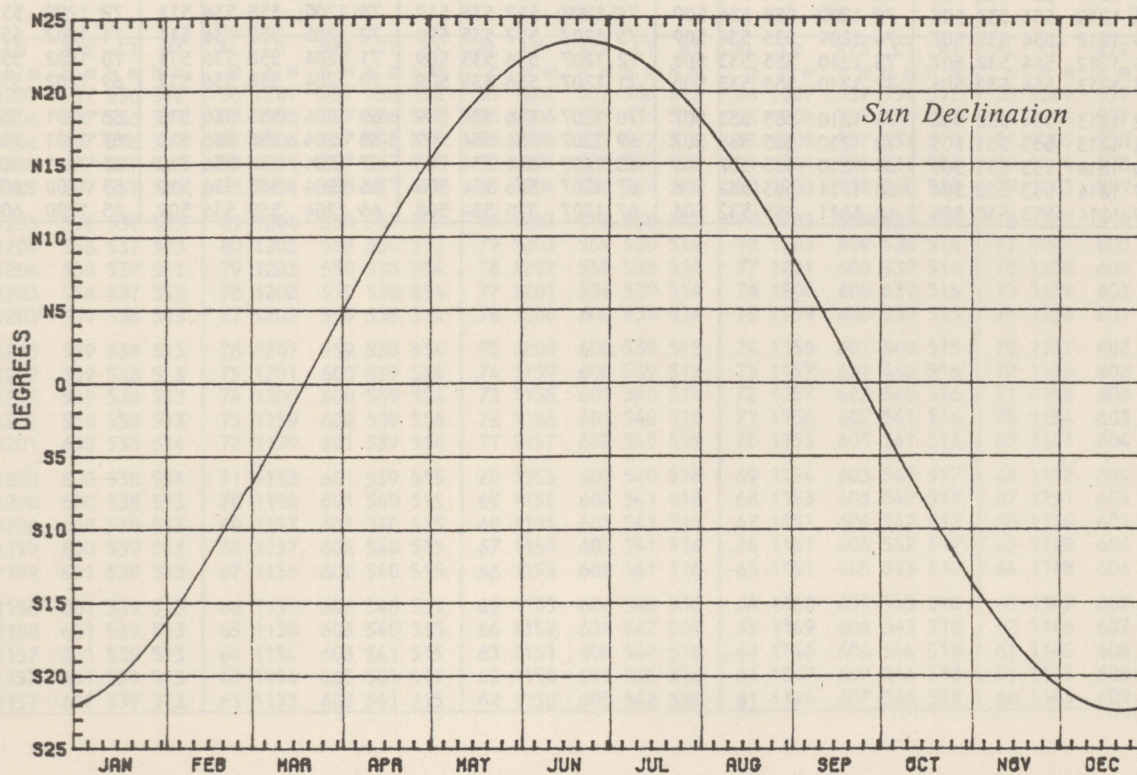


Table 2

Latitude and Declination **SAME**Latitude and Declination **OPPOSITE**

DEC	LAT. 2					LAT. 1					LAT. 0					LAT. 1					LAT. 2				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
0	88	1207	557	536	512	89	1207	557	536	512	90	1207	557	536	512	89	1207	557	536	512	88	1207	557	536	512
1	89	1207	557	536	512	90	1207	557	536	512	89	1207	557	536	512	88	1207	557	536	512	87	1206	557	536	512
2	90	1207	556	536	512	89	1207	557	536	512	88	1207	557	536	512	87	1206	557	536	512	86	1206	557	536	512
3	89	1208	556	536	511	88	1207	556	536	512	87	1207	557	536	512	86	1206	557	536	512	85	1206	557	536	512
4	88	1208	556	535	511	87	1207	556	536	512	86	1207	557	536	512	85	1206	557	536	512	84	1206	557	536	512
5	87	1208	556	535	511	86	1207	556	536	511	85	1207	557	536	512	84	1206	557	536	512	83	1205	557	537	512
6	86	1208	556	535	511	85	1208	556	535	511	84	1207	557	536	512	83	1206	557	536	512	82	1205	557	537	513
7	85	1209	556	535	511	84	1208	556	535	511	83	1207	557	536	512	82	1206	557	536	512	81	1205	558	537	513
8	84	1209	556	535	510	83	1208	556	535	511	82	1207	557	536	512	81	1206	557	536	512	80	1204	558	537	513
9	83	1209	555	534	510	82	1208	556	535	511	81	1207	557	536	511	80	1205	557	536	512	79	1204	558	537	513
10	82	1210	555	534	510	81	1208	556	535	511	80	1207	557	536	511	79	1205	557	536	512	78	1204	558	537	513
11	81	1210	555	534	509	80	1208	556	535	510	79	1207	557	536	511	78	1205	557	536	512	77	1204	558	537	513
12	80	1210	555	534	509	79	1209	556	535	510	78	1207	557	535	511	77	1205	557	536	512	76	1203	558	537	513
13	79	1211	555	533	509	78	1209	556	534	510	77	1207	557	535	511	76	1205	558	536	512	75	1203	558	537	513
14	78	1211	555	533	508	77	1209	556	534	509	76	1207	557	535	511	75	1205	558	536	512	74	1203	559	537	513
15	77	1211	554	533	508	76	1209	555	534	509	75	1207	557	535	510	74	1205	558	536	511	73	1203	559	537	512
16	76	1212	554	533	508	75	1209	555	534	509	74	1207	557	535	510	73	1205	558	536	511	72	1202	559	537	512
17	75	1212	554	532	507	74	1209	555	534	509	73	1207	557	535	510	72	1205	558	536	511	71	1202	559	537	512
18	74	1212	554	532	507	73	1210	555	533	508	72	1207	556	535	509	71	1204	558	536	511	70	1202	559	537	512
19	73	1213	554	532	506	72	1210	555	533	508	71	1207	556	535	509	70	1204	558	536	511	69	1202	559	537	512
20	72	1213	554	532	506	71	1210	555	533	507	70	1207	556	534	509	69	1204	558	536	510	68	1201	559	537	512
21	71	1213	553	531	505	70	1210	555	533	507	69	1207	556	534	509	68	1204	558	536	510	67	1201	559	537	512
22	70	1214	553	531	505	69	1210	555	532	506	68	1207	556	534	508	67	1204	558	536	510	66	1201	600	537	511
23	69	1214	553	530	504	68	1211	555	532	506	67	1207	556	534	508	66	1204	558	536	510	65	1200	600	537	511
23.5	69	1214	553	530	504	68	1211	555	532	506	67	1207	556	534	508	66	1204	558	536	509	65	1200	600	537	511

Table 2, Latitude and Declination SAME

	LAT. 3					LAT. 4					LAT. 5					LAT. 6					LAT. 7					
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	
o	o	h	m	h	m	h	m	h	m	h	o	h	m	h	m	h	o	h	m	h	m	o	h	m	h	m
0	87	1207	557	536	512	86	1207	557	536	512	85	1207	557	536	512	84	1207	557	536	512	83	1207	557	536	512	
1	88	1207	556	536	512	87	1207	556	536	512	86	1207	556	536	511	85	1208	556	535	511	84	1208	556	535	511	
2	89	1208	556	536	511	88	1208	556	535	511	87	1208	556	535	511	86	1208	556	535	511	85	1209	556	535	511	
3	90	1208	556	535	511	89	1208	556	535	511	88	1209	556	535	511	87	1209	555	535	510	86	1210	555	534	510	
4	89	1208	556	535	511	90	1209	556	535	511	89	1210	555	534	510	88	1210	555	534	510	87	1211	555	534	509	
5	88	1209	556	535	511	89	1210	555	534	510	90	1210	555	534	510	89	1211	555	534	509	88	1212	554	533	509	
6	87	1209	555	535	510	88	1210	555	534	510	89	1211	555	534	509	90	1212	554	533	509	89	1213	554	533	508	
7	86	1210	555	534	510	87	1211	555	534	509	88	1212	554	533	509	89	1213	554	533	508	90	1214	553	532	508	
8	85	1210	555	534	510	86	1211	554	533	509	87	1212	554	533	508	88	1214	553	532	508	89	1215	553	532	507	
9	84	1211	555	534	509	85	1212	554	533	509	86	1213	553	532	508	87	1214	553	532	507	88	1216	552	531	506	
10	83	1211	554	533	509	84	1212	554	533	508	85	1214	553	532	507	86	1215	552	531	507	87	1217	552	530	506	
11	82	1211	554	533	509	83	1213	553	532	508	84	1215	553	532	507	85	1216	552	531	506	86	1218	551	530	505	
12	81	1212	554	533	508	82	1214	553	532	507	83	1215	552	531	506	84	1217	551	530	505	85	1219	551	529	504	
13	80	1212	554	533	508	81	1214	553	532	507	82	1216	552	531	506	83	1218	551	530	505	84	1220	550	529	504	
14	79	1213	554	532	507	80	1215	553	531	506	81	1217	552	530	505	82	1219	551	529	504	83	1221	550	528	503	
15	78	1213	553	532	507	79	1216	552	531	506	80	1218	551	530	505	81	1220	550	529	503	82	1222	549	527	502	
16	77	1214	553	532	506	78	1216	552	530	505	79	1218	551	529	504	80	1221	550	528	503	81	1223	548	527	501	
17	76	1214	553	531	506	77	1217	552	530	505	78	1219	550	529	503	79	1222	549	527	502	80	1224	548	526	501	
18	75	1215	553	531	505	76	1217	551	529	504	77	1220	550	528	503	78	1223	549	527	501	79	1225	547	525	500	
19	74	1215	552	530	505	75	1218	551	529	503	76	1221	550	528	502	77	1224	548	526	500	78	1226	547	525	459	
20	73	1216	552	530	504	74	1219	551	529	503	75	1222	549	527	501	76	1225	548	525	500	77	1228	546	524	458	
21	72	1216	552	530	504	73	1219	550	528	502	74	1223	549	526	500	75	1226	547	525	459	76	1229	546	523	457	
22	71	1217	552	529	503	72	1220	550	528	501	73	1223	548	526	500	74	1227	547	524	458	75	1230	545	522	456	
23	70	1217	551	529	502	71	1221	550	527	501	72	1224	548	525	459	73	1228	546	523	457	74	1231	544	522	455	
23.5	70	1218	551	529	502	71	1221	549	527	500	72	1225	548	525	458	73	1228	546	523	456	74	1232	544	521	455	

Latitude and Declination OPPOSITE

	LAT. 3					LAT. 4					LAT. 5					LAT. 6					LAT. 7					
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	
o	o	h	m	h	m	h	m	h	m	h	o	h	m	h	m	h	o	h	m	h	m	o	h	m	h	m
0	87	1207	557	536	512	86	1207	557	536	512	85	1207	557	536	512	84	1207	557	536	512	83	1207	557	536	512	
1	86	1206	557	536	512	85	1206	557	536	512	84	1206	557	536	512	83	1206	557	536	512	82	1206	557	536	512	
2	85	1206	557	536	512	84	1206	557	536	512	83	1205	557	537	512	82	1205	557	537	513	81	1205	558	537	513	
3	84	1205	557	537	513	83	1205	557	537	513	82	1205	558	537	513	81	1204	558	537	513	80	1204	558	537	513	
4	83	1205	557	537	513	82	1204	558	537	513	81	1204	558	537	513	80	1203	558	538	513	79	1203	559	538	514	
5	82	1205	558	537	513	81	1204	558	537	513	80	1203	558	538	513	79	1203	559	538	514	78	1202	559	538	514	
6	81	1204	558	537	513	80	1203	558	538	513	79	1203	559	538	514	78	1202	559	538	514	77	1201	600	539	514	
7	80	1204	558	537	513	79	1203	559	538	514	78	1202	559	538	514	77	1201	600	539	514	76	1200	600	539	515	
8	79	1203	558	537	513	78	1202	559	538	514	77	1201	559	539	514	76	1200	600	539	515	75	1159	601	540	515	
9	78	1203	559	538	513	77	1202	559	538	514	76	1200	600	539	514	75	1159	600	539	515	74	1158	601	540	516	
10	77	1203	559	538	513	76	1201	559	538	514	75	1200	600	539	515	74	1158	601	540	515	73	1157	602	540	516	
11	76	1202	559	538	513	75	1201	600	539	514	74	1159	600	539	515	73	1157	601	540	516	72	1156	602	541	516	
12	75	1202	559	538	513	74	1200	600	539	514	73	1158	601	540	515	72	1157	602	540	516	71	1155	603	541	517	
13	74	1201	559	538	513	73	1159	600	539	514	72	1158	601	540	515	71	1156	602	541	516	70	1154	603	542	517	
14	73	1201	600	538	514	72	1159	601	539	514	71	1157	602	540	515	70	1155	603	541	516	69	1153	604	542	517	
15	72	1200	600	538	514	71	1158	601	539	515	70	1156	602	540	516	69	1154	603	541	517	68	1152	604	543	518	
16	71	1200	600	538	513	70	1158	601	540	515	69	1155	602	541	516	68	1153	603	542	517	67	1151	605	543	518	
17	70	1200	600	539	513	69	1157	601	540	515	68	1155	603	541	516	67	1152	604	542	517	66	1150	605	543	518	
18	69	1159	600	539	513	68	1157	602	540	515	67	1154	603	541	516	66	1151	604	542	517	65	1149	606	544	518	
19	68	1159	601	539	513	67	1156	602	540	515	66	1153	603	541	516	65	1151	605	543	517	64	1148	606	544	519	
20	67	1158	601	539	513	66	1155	602	540	515	65	1153	604	542	516	64	1150	605	543	518	63	1147	607	545	519	
21	66	1158	601	539	513	65	1155	603	540	515	64	1152	604	542	516	63	1149	606	543	518	62	1146	607	545	519	
22	65	1157	601	539	513	64	1154	603	541	515	63	1151	604	542	516	62	1148	606	544	518	61	1145	608	545	519	
23	64	1157	601	539	513	63	1154	603	541	515	62	1150	605	542	516	61	1147	607	544	518	60	1143	608	546	520	
23.5	64	1157	602	539	513	63	1153	603	541	515	62	1150	605	542	516	61	1146	607	544	518	60	1143	609	546	520	

Table 2, Latitude and Declination SAME

DEC	LAT. 8					LAT. 9					LAT.10					LAT.11					LAT.12				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
0	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	82	1207	557	536	512	81	1207	557	536	511	80	1207	557	536	511	79	1207	557	536	511	78	1207	557	535	511
1	83	1208	556	535	511	82	1208	556	535	511	81	1208	556	535	511	80	1208	556	535	510	79	1209	556	535	510
2	84	1209	556	535	510	83	1209	555	534	510	82	1210	555	534	510	81	1210	555	534	509	80	1210	555	534	509
3	85	1210	555	534	510	84	1211	555	534	509	83	1211	554	533	509	82	1211	554	533	509	81	1212	554	533	508
4	86	1211	554	533	509	85	1212	554	533	509	84	1212	554	533	508	83	1213	553	532	508	82	1214	553	532	507
5	87	1212	554	533	508	86	1213	553	532	508	85	1214	553	532	507	84	1215	553	532	507	83	1215	552	531	506
6	88	1214	553	532	508	87	1214	553	532	507	86	1215	552	531	507	85	1216	552	531	506	84	1217	551	530	505
7	89	1215	553	532	507	88	1216	552	531	506	87	1217	552	530	506	86	1218	551	530	505	85	1219	551	529	504
8	90	1216	552	531	506	89	1217	551	530	506	88	1218	551	530	505	87	1219	550	529	504	86	1221	550	528	503
9	89	1217	551	530	506	90	1218	551	530	505	89	1220	550	529	504	88	1221	550	528	503	87	1222	549	527	502
10	88	1218	551	530	505	89	1220	550	529	504	90	1221	549	528	503	89	1223	549	527	502	88	1224	548	526	501
11	87	1219	550	529	504	88	1221	550	528	503	89	1223	549	527	502	90	1224	548	526	501	89	1226	547	525	500
12	86	1221	550	528	503	87	1222	549	527	502	88	1224	548	526	501	89	1226	547	525	500	90	1228	546	524	459
13	85	1222	549	528	503	86	1224	548	527	501	87	1226	547	526	500	88	1228	546	525	459	89	1230	545	523	458
14	84	1223	548	527	502	85	1225	547	526	501	86	1227	546	525	459	87	1229	545	524	458	88	1231	544	522	457
15	83	1224	548	526	501	84	1226	547	525	500	85	1229	546	524	458	86	1231	545	523	457	87	1233	543	521	456
16	82	1225	547	525	500	83	1228	546	524	459	84	1230	545	523	457	85	1233	544	522	456	86	1235	542	520	454
17	81	1227	547	525	459	82	1229	545	523	458	83	1232	544	522	456	84	1234	543	521	455	85	1237	542	519	453
18	80	1228	546	524	458	81	1231	545	523	457	82	1233	543	521	455	83	1236	542	520	454	84	1239	541	518	452
19	79	1229	545	523	457	80	1232	544	522	456	81	1235	542	520	454	82	1238	541	519	452	83	1241	540	517	451
20	78	1231	545	522	456	79	1234	543	521	455	80	1237	542	519	453	81	1240	540	518	451	82	1243	539	516	449
21	77	1232	544	522	455	78	1235	542	520	453	79	1238	541	518	452	80	1242	539	516	450	81	1245	538	515	448
22	76	1233	543	521	454	77	1237	542	519	452	78	1240	540	517	450	79	1243	538	515	448	80	1247	537	514	447
23	75	1235	543	520	453	76	1238	541	518	451	77	1242	539	516	449	78	1245	537	514	447	79	1249	536	512	445
23.5	75	1235	542	519	453	76	1239	541	518	451	77	1243	539	516	449	78	1246	537	514	446	79	1250	535	512	444

Latitude and Declination OPPOSITE

DEC	LAT. 8					LAT. 9					LAT.10					LAT.11					LAT.12				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
0	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	82	1207	557	536	512	81	1207	557	536	511	80	1207	557	536	511	79	1207	557	536	511	78	1207	557	535	511
1	81	1206	557	536	512	80	1205	557	536	512	79	1205	557	536	512	78	1205	557	536	512	77	1205	557	536	512
2	80	1204	558	537	513	79	1204	558	537	513	78	1204	558	537	513	77	1204	558	537	513	76	1203	558	537	513
3	79	1203	558	537	513	78	1203	559	538	513	77	1203	559	538	513	76	1202	559	538	513	75	1202	559	538	513
4	78	1202	559	538	514	77	1202	559	538	514	76	1201	559	538	514	75	1201	600	539	514	74	1200	600	539	514
5	77	1201	559	539	514	76	1200	600	539	514	75	1200	600	539	515	74	1159	600	539	515	73	1158	601	540	515
6	76	1200	600	539	515	75	1159	600	539	515	74	1158	601	540	515	73	1157	601	540	516	72	1157	602	540	516
7	75	1159	601	540	515	74	1158	601	540	516	73	1157	602	540	516	72	1156	602	541	516	71	1155	603	541	517
8	74	1158	601	540	516	73	1157	602	541	516	72	1155	602	541	517	71	1154	603	542	517	70	1153	603	542	517
9	73	1157	602	541	516	72	1155	602	541	517	71	1154	603	542	517	70	1153	604	542	518	69	1151	604	543	518
10	72	1155	602	541	517	71	1154	603	542	517	70	1153	604	542	518	69	1151	604	543	518	68	1150	605	544	519
11	71	1154	603	542	517	70	1153	604	542	518	69	1151	604	543	518	68	1150	605	544	519	67	1148	606	545	520
12	70	1153	603	542	517	69	1151	604	543	518	68	1150	605	544	519	67	1148	606	545	520	66	1146	607	545	520
13	69	1152	604	543	518	68	1150	605	543	519	67	1148	606	544	519	66	1146	607	545	520	65	1144	608	546	521
14	68	1151	605	543	518	67	1149	606	544	519	66	1147	607	545	520	65	1145	608	546	521	64	1143	609	547	522
15	67	1150	605	544	519	66	1148	606	545	520	65	1145	607	546	521	64	1143	608	547	522	63	1141	610	548	522
16	66	1149	606	544	519	65	1146	607	545	520	64	1144	608	546	521	63	1142	609	547	522	62	1139	610	548	523
17	65	1147	606	545	519	64	1145	608	546	520	63	1142	609	547	522	62	1140	610	548	523	61	1137	611	549	524
18	64	1146	607	545	520	63	1144	608	546	521	62	1141	610	548	522	61	1138	611	549	523	60	1135	612	550	524
19	63	1145	608	545	520	62	1142	609	547	521	61	1139	610	548	523	60	1136	612	550	524	59	1134	613	551	525
20	62	1144	608	546	520	61	1141	610	547	522	60	1138	611	549	523	59	1135	613	550	524	58	1132	614	552	526
21	61	1142	609	546	521	60	1139	610	548	522	59	1136	612	549	524	58	1133	613	551	525	57	1130	615	552	526
22	60	1141	609	547	521	59	1138	611	549	522	58	1135	613	550	524	57	1131	614	552	526	56	1128	616	553	527
23	59	1140	610	547	521	58	1137	612	549	523	57	1133	613	551	524	56	1130	615	552	526	55	1126	617	554	528
23.5	59	1139	610	548	521	58	1136	612	549	523	57	1132	614	551	525	56	1129	616	553	526	55	1125	617	554	528

Table 2, Latitude and Declination SAME

DEC	LAT.13					LAT.14					LAT.15					LAT.16					LAT.17				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
0	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	77	1207	557	535	511	76	1207	557	535	511	75	1207	557	535	510	74	1207	557	535	510	73	1207	557	535	510
1	78	1209	556	534	510	77	1209	556	534	509	76	1209	555	534	509	75	1209	555	534	509	74	1209	555	534	509
2	79	1211	555	533	509	78	1211	555	533	508	77	1211	554	533	508	76	1212	554	533	508	75	1212	554	532	507
3	80	1212	554	533	508	79	1213	554	532	507	78	1213	553	532	507	77	1214	553	532	506	76	1214	553	531	506
4	81	1214	553	532	507	80	1215	553	531	506	79	1216	552	531	506	78	1216	552	530	505	77	1217	552	530	505
5	82	1216	552	531	506	81	1217	552	530	505	80	1218	551	530	505	79	1218	551	529	504	78	1219	550	529	503
6	83	1218	551	530	505	82	1219	551	529	504	81	1220	550	529	503	80	1221	550	528	503	79	1222	549	527	502
7	84	1220	550	529	504	83	1221	550	528	503	82	1222	549	527	502	81	1223	548	527	501	80	1224	548	526	501
8	85	1222	549	528	503	84	1223	548	527	502	83	1224	548	526	501	82	1225	547	525	500	81	1227	547	525	459
9	86	1224	548	527	501	85	1225	547	526	501	84	1226	547	525	500	83	1228	546	524	459	82	1229	545	523	458
10	87	1226	547	526	500	86	1227	546	525	459	85	1229	546	524	458	84	1230	545	523	457	83	1232	544	522	456
11	88	1228	546	525	459	87	1229	545	524	458	86	1231	545	523	457	85	1233	544	522	456	84	1234	543	521	455
12	89	1230	545	523	458	88	1231	544	522	457	87	1233	543	521	456	86	1235	542	520	454	85	1237	542	519	453
13	90	1231	544	522	457	89	1233	543	521	456	88	1235	542	520	454	87	1238	541	519	453	86	1240	540	518	452
14	89	1233	543	521	456	90	1236	542	520	454	89	1238	541	519	453	88	1240	540	518	452	87	1242	539	516	450
15	88	1235	542	520	454	89	1238	541	519	453	90	1240	540	518	451	89	1242	539	516	450	88	1245	538	515	448
16	87	1238	541	519	453	88	1240	540	518	452	89	1242	539	516	450	90	1245	538	515	448	89	1248	536	514	447
17	86	1240	540	518	452	87	1242	539	516	450	88	1245	538	515	448	89	1248	536	514	447	90	1250	535	512	445
18	85	1242	539	517	450	86	1244	538	515	449	87	1247	536	514	447	88	1250	535	512	445	89	1253	534	511	443
19	84	1244	538	515	449	85	1247	537	514	447	86	1250	535	512	445	87	1253	534	511	444	88	1256	532	509	442
20	83	1246	537	514	447	84	1249	535	513	446	85	1252	534	511	444	86	1255	532	509	442	87	1259	531	507	440
21	82	1248	536	513	446	83	1251	534	511	444	84	1255	533	509	442	85	1258	531	508	440	86	1301	529	506	438
22	81	1250	535	512	445	82	1254	533	510	442	83	1257	531	508	440	84	1301	530	506	438	85	1304	528	504	436
23	80	1252	534	510	443	81	1256	532	508	441	82	1300	530	507	439	83	1304	528	504	436	84	1307	526	502	434
23.5	80	1254	533	510	442	81	1257	531	508	440	82	1301	529	506	438	83	1305	528	504	435	84	1309	526	502	433

Latitude and Declination OPPOSITE

DEC	LAT.13					LAT.14					LAT.15					LAT.16					LAT.17				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
0	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	77	1207	557	535	511	76	1207	557	535	511	75	1207	557	535	510	74	1207	557	535	510	73	1207	557	535	510
1	76	1205	558	536	512	75	1205	558	536	512	74	1205	558	536	511	73	1205	558	536	511	72	1205	558	536	511
2	75	1203	558	537	513	74	1203	559	537	513	73	1203	559	537	512	72	1202	559	537	512	71	1202	559	537	512
3	74	1201	559	538	513	73	1201	600	538	514	72	1200	600	538	514	71	1200	600	538	513	70	1200	600	539	513
4	73	1159	600	539	514	72	1159	601	539	514	71	1158	601	539	515	70	1158	601	540	515	69	1157	601	540	515
5	72	1158	601	540	515	71	1157	602	540	515	70	1156	602	540	516	69	1155	602	541	516	68	1155	603	541	516
6	71	1156	602	541	516	70	1155	603	541	516	69	1154	603	541	517	68	1153	603	542	517	67	1152	604	542	517
7	70	1154	603	542	517	69	1153	604	542	517	68	1152	604	543	518	67	1151	605	543	518	66	1150	605	543	518
8	69	1152	604	543	518	68	1151	605	543	518	67	1150	605	544	519	66	1149	606	544	519	65	1147	606	545	519
9	68	1150	605	543	519	67	1149	606	544	519	66	1148	606	545	520	65	1146	607	545	520	64	1145	608	546	520
10	67	1148	606	544	519	66	1147	607	545	520	65	1145	607	546	521	64	1144	608	546	521	63	1142	609	547	522
11	66	1146	607	545	520	65	1145	608	546	521	64	1143	608	547	522	63	1142	609	547	522	62	1140	610	548	523
12	65	1144	608	546	521	64	1143	609	547	522	63	1141	610	548	522	62	1139	610	548	523	61	1137	611	549	524
13	64	1143	609	547	522	63	1141	610	548	523	62	1139	611	549	523	61	1137	612	550	524	60	1135	613	550	525
14	63	1141	610	548	523	62	1139	611	549	523	61	1136	612	550	524	60	1134	613	551	525	59	1132	614	552	526
15	62	1139	611	549	523	61	1136	612	550	524	60	1134	613	551	525	59	1132	614	552	526	58	1130	615	553	527
16	61	1137	612	550	524	60	1134	613	551	525	59	1132	614	552	526	58	1130	615	553	527	57	1127	616	554	528
17	60	1135	613	550	525	59	1132	614	552	526	58	1130	615	553	527	57	1127	616	554	528	56	1124	618	555	529
18	59	1133	614	551	526	58	1130	615	553	527	57	1127	616	554	528	56	1125	618	555	529	55	1122	619	556	530
19	58	1131	615	552	526	57	1128	616	554	528	56	1125	618	555	529	55	1122	619	556	530	54	1119	620	558	531
20	57	1129	616	553	527	56	1126	617	555	528	55	1123	619	556	530	54	1119	620	557	531	53	1116	622	559	532
21	56	1127	617	554	528	55	1123	618	555	529	54	1120	620	557	531	53	1117	622	559	532	52	1114	623	600	533
22	55	1125	618	555	529	54	1121	619	556	530	53	1118	621	558	532	52	1114	623	600	533	51	1111	625	601	535
23	54	1122	619	556	529	53	1119	621	557	531	52	1115	622	559	532	51	1112	624	601	534	50	1108	626	603	536
23.5	54	1121	619	556	530	53	1118	621	558	531	52	1114	623	600	533	51	1110	625	601	534	50	1107	627	603	536

Table 2, Latitude and Declination SAME

	LAT.18					LAT.19					LAT.20					LAT.21					LAT.22									
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT					
o	o	h	m	h	m	h	m	h	m	h	o	h	m	h	m	h	o	h	m	h	m	h	o	h	m	h	m	h	m	
0	72	1207	556	535	509	71	1207	556	535	509	70	1207	556	534	509	69	1207	556	534	509	68	1207	556	534	508	69	1210	555	532	506
1	73	1210	555	533	508	72	1210	555	533	508	71	1210	555	533	507	70	1210	555	533	507	69	1210	555	533	507	70	1214	553	531	505
2	74	1212	554	532	507	73	1213	554	532	506	72	1213	554	532	506	71	1213	553	531	505	70	1214	553	531	505	71	1217	552	529	503
3	75	1215	553	531	505	74	1215	552	530	505	73	1216	552	530	504	72	1216	552	530	504	71	1217	552	529	503	72	1220	550	528	501
4	76	1217	551	529	504	75	1218	551	529	503	74	1219	551	529	503	73	1219	550	528	502	72	1220	550	528	501	73	1223	548	526	500
5	77	1220	550	528	503	76	1221	550	528	502	75	1222	549	527	501	74	1223	549	526	500	73	1223	548	526	500	74	1227	547	524	458
6	78	1223	549	527	501	77	1224	548	526	500	76	1225	548	525	500	75	1226	547	525	459	74	1227	547	524	458	75	1230	545	522	456
7	79	1225	547	525	500	78	1226	547	525	459	77	1228	546	524	458	76	1229	546	523	457	75	1230	545	522	456	76	1233	543	521	454
8	80	1228	546	524	458	79	1229	545	523	457	78	1231	545	522	456	77	1232	544	522	455	76	1233	543	521	454	77	1237	542	519	452
9	81	1231	545	523	457	80	1232	544	522	456	79	1234	543	521	455	78	1235	542	520	453	77	1237	542	519	452	78	1240	540	517	450
10	82	1233	543	521	455	81	1235	542	520	454	80	1237	542	519	453	79	1238	541	518	452	78	1240	540	517	450	79	1243	538	515	448
11	83	1236	542	520	454	82	1238	541	519	452	81	1240	540	518	451	80	1242	539	516	450	79	1243	538	515	448	80	1247	537	514	447
12	84	1239	541	518	452	83	1241	540	517	451	82	1243	539	516	449	81	1245	538	515	448	80	1247	537	514	447	81	1250	535	512	445
13	85	1242	539	517	450	84	1244	538	515	449	83	1246	537	514	447	82	1248	536	513	446	81	1250	535	512	445	82	1254	533	510	442
14	86	1244	538	515	449	85	1247	537	514	447	84	1249	535	513	446	83	1251	534	511	444	82	1254	533	510	442	83	1257	531	508	440
15	87	1247	536	514	447	86	1250	535	512	445	85	1252	534	511	444	84	1255	533	509	442	83	1257	531	508	440	84	1301	530	506	438
16	88	1250	535	512	445	87	1253	534	511	444	86	1255	532	509	442	85	1258	531	508	440	84	1301	530	506	438	85	1304	528	504	436
17	89	1253	534	511	443	88	1256	532	509	442	87	1259	531	507	440	86	1301	529	506	438	85	1304	528	504	436	86	1308	526	502	434
18	90	1256	532	509	442	89	1259	531	507	440	88	1302	529	506	438	87	1305	528	504	436	86	1308	526	502	434	87	1312	524	500	432
19	89	1259	531	507	440	90	1302	529	506	438	89	1305	527	504	436	88	1308	526	502	434	87	1312	524	500	432	88	1315	522	458	429
20	88	1302	529	506	438	89	1305	527	504	436	90	1309	526	502	434	89	1312	524	500	431	88	1315	522	458	429	89	1319	520	456	427
21	87	1305	528	504	436	88	1308	526	502	434	89	1312	524	500	431	90	1316	522	458	429	89	1319	520	456	427	90	1323	518	454	424
22	86	1308	526	502	434	87	1312	524	500	432	88	1315	522	458	429	89	1319	520	456	427	88	1323	519	454	424	89	1327	517	452	422
23	85	1311	524	500	432	86	1315	523	458	429	87	1319	521	456	427	88	1323	519	454	424	89	1327	517	452	422	90	1329	516	451	421
23.5	85	1313	524	459	431	86	1317	522	457	428	87	1321	520	455	426	88	1325	518	453	423	89	1329	516	451	421					

Latitude and Declination OPPOSITE

	LAT.18					LAT.19					LAT.20					LAT.21					LAT.22						
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT		
o	o	h	m	h	m	h	m	h	m	h	o	h	m	h	m	h	o	h	m	h	m	h	o	h	m	h	m
0	72	1207	556	535	509	71	1207	556	535	509	70	1207	556	534	509	69	1207	556	534	509	68	1207	556	534	508		
1	71	1204	558	536	511	70	1204	558	536	511	69	1204	558	536	510	68	1204	558	536	510	67	1204	558	536	510		
2	70	1202	559	537	512	69	1202	559	537	512	68	1201	559	537	512	67	1201	559	537	512	66	1201	559	537	511		
3	69	1159	600	539	513	68	1159	601	539	513	67	1158	601	539	513	66	1158	601	539	513	65	1157	601	539	513		
4	68	1157	602	540	515	67	1156	602	540	515	66	1155	602	540	515	65	1155	603	540	515	64	1154	603	541	515		
5	67	1154	603	541	516	66	1153	603	541	516	65	1153	604	542	516	64	1152	604	542	516	63	1151	604	542	516		
6	66	1151	604	542	517	65	1151	605	543	517	64	1150	605	543	518	63	1149	606	543	518	62	1148	606	544	518		
7	65	1149	606	544	518	64	1148	606	544	519	63	1147	607	545	519	62	1146	607	545	519	61	1145	608	545	519		
8	64	1146	607	545	520	63	1145	608	545	520	62	1144	608	546	520	61	1142	609	546	521	60	1141	609	547	521		
9	63	1144	608	546	521	62	1142	609	547	521	61	1141	610	547	522	60	1139	610	548	522	59	1138	611	549	522		
10	62	1141	610	548	522	61	1139	610	548	523	60	1138	611	549	523	59	1136	612	549	524	58	1135	613	550	524		
11	61	1138	611	549	523	60	1136	612	550	524	59	1135	613	550	524	58	1133	613	551	525	57	1131	614	552	526		
12	60	1135	612	550	524	59	1134	613	551	525	58	1132	614	552	526	57	1130	615	552	526	56	1128	616	553	527		
13	59	1133	614	551	526	58	1131	615	552	526	57	1129	616	553	527	56	1127	617	554	528	55	1125	618	555	529		
14	58	1130	615	553	527	57	1128	616	554	528	56	1126	617	555	528	55	1123	618	555	529	54	1121	619	556	530		
15	57	1127	616	554	528	56	1125	618	555	529	55	1123	619	556	530	54	1120	620	557	531	53	1118	621	558	532		
16	56	1125	618	555	529	55	1122	619	556	530	54	1119	620	557	531	53	1117	622	559	532	52	1114	623	600	533		
17	55	1122	619	556	530	54	1119	620	558	531	53	1116	622	559	532	52	1114	623	600	533	51	1111	625	601	535		
18	54	1119	621	558	531	53	1116	622	559	533	52	1113	623	600	534	51	1110	625	602	535	50	1107	626	603	536		
19	53	1116	622	559	533	52	1113	623	600	534	51	1110	625	602	535	50	1107	627	603	536	49	1104	628	605	537		
20	52	1113	623	600	534	51	1110	625	602	535	50	1107	627	603	536	49	1103	628	605	538	48	1100	630	606	539		
21	51	1110	625	602	535	50	1107	627	603	536	49	1103	628	605	538	48	1100	630	606	539	47	1056	632	608	540		
22	50	1107	626	603	536	49	1104	628	605	537	48	1100	630	606	539	47	1056	632	608	540	46	1053	634	611	543		
23	49	1104	628	604	537	48	1100	630	606	539	47	1057	632	608	540	46	1053	634	609	542	45	1049	636	611	543		
23.5	49	1103	629	605	538	48	1059	631	607	539	47	1055	633	608	541	46	1051	634	610	543	45	1047	636	612	544		

Table 2, Latitude and Declination SAME

DEC	LAT.23					LAT.24					LAT.25					LAT.26					LAT.27				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
0	o	h	m	h	m	h	m	h	m	h	o	h	m	h	m	h	o	h	m	h	m	h	o	h	m
0	67	1207	556	534	508	66	1207	556	534	507	65	1207	556	534	507	64	1207	556	533	507	63	1207	556	533	506
1	68	1211	555	532	506	67	1211	555	532	506	66	1211	554	532	505	65	1211	554	531	504	64	1212	554	531	504
2	69	1214	553	530	504	68	1214	553	530	504	67	1215	553	530	503	66	1215	552	529	502	65	1216	552	529	502
3	70	1217	551	529	502	69	1218	551	528	502	68	1219	551	528	501	67	1219	550	527	500	66	1220	550	527	500
4	71	1221	550	527	501	70	1222	549	526	500	69	1222	549	526	459	68	1223	548	525	458	67	1224	548	525	457
5	72	1224	548	525	459	71	1225	547	525	458	70	1226	547	524	457	69	1227	546	523	456	68	1228	546	523	455
6	73	1228	546	523	457	72	1229	546	523	456	71	1230	545	522	455	70	1231	545	521	454	69	1232	544	520	453
7	74	1231	544	522	455	73	1232	544	521	454	72	1234	543	520	453	71	1235	543	519	452	70	1236	542	518	451
8	75	1235	543	520	453	74	1236	542	519	452	73	1238	541	518	451	72	1239	541	517	450	71	1240	540	516	448
9	76	1238	541	518	451	75	1240	540	517	450	74	1241	539	516	449	73	1243	539	515	447	72	1245	538	514	446
10	77	1242	539	516	449	76	1243	538	515	448	75	1245	537	514	447	74	1247	536	513	445	73	1249	536	512	444
11	78	1245	537	514	447	77	1247	536	513	446	76	1249	535	512	444	75	1251	534	511	443	74	1253	533	510	441
12	79	1249	536	512	445	78	1251	535	511	444	77	1253	533	510	442	76	1255	532	509	440	75	1257	531	507	439
13	80	1252	534	510	443	79	1255	533	509	441	78	1257	531	508	440	77	1259	530	506	438	76	1302	529	505	436
14	81	1256	532	508	441	80	1259	531	507	439	79	1301	529	506	437	78	1304	528	504	436	77	1306	527	503	434
15	82	1300	530	507	439	81	1302	529	505	437	80	1305	527	503	435	79	1308	526	502	433	78	1311	525	500	431
16	83	1304	528	504	436	82	1306	527	503	435	81	1309	525	501	433	80	1312	524	500	431	79	1315	522	458	428
17	84	1307	526	502	434	83	1310	525	501	432	82	1313	523	459	430	81	1316	522	457	428	80	1320	520	455	426
18	85	1311	524	500	432	84	1314	523	459	430	83	1318	521	457	428	82	1321	520	455	425	81	1324	518	453	423
19	86	1315	523	458	429	85	1318	521	456	427	84	1322	519	454	425	83	1325	517	452	423	82	1329	516	450	420
20	87	1319	521	456	427	86	1322	519	454	425	85	1326	517	452	422	84	1330	515	450	420	83	1334	513	448	417
21	88	1323	519	454	424	87	1327	517	452	422	86	1331	515	450	419	85	1334	513	447	417	84	1338	511	445	414
22	89	1327	517	452	422	88	1331	515	449	419	87	1335	513	447	417	86	1339	510	445	414	85	1343	508	442	411
23	90	1331	514	449	419	89	1335	512	447	417	88	1339	510	445	414	87	1344	508	442	411	86	1348	506	440	408
23.5	90	1333	513	448	418	90	1337	511	446	415	89	1342	509	443	412	88	1346	507	441	409	87	1351	505	438	406

Latitude and Declination OPPOSITE

	LAT.23					LAT.24					LAT.25					LAT.26					LAT.27					
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	
o	o	h	m	h	m	h	o	h	m	h	o	h	m	h	m	o	h	m	h	m	h	o	h	m	h	m
0	67	1207	556	534	508	66	1207	556	534	507	65	1207	556	534	507	64	1207	556	533	507	63	1207	556	533	506	
1	66	1204	558	536	510	65	1204	558	536	509	64	1204	558	535	509	63	1204	558	535	508	62	1203	558	535	508	
2	65	1200	600	537	511	64	1200	600	537	511	63	1200	600	537	511	62	1200	600	537	510	61	1159	600	537	510	
3	64	1157	601	539	513	63	1157	602	539	513	62	1156	602	539	513	61	1156	602	539	512	60	1155	602	539	512	
4	63	1154	603	541	515	62	1153	603	541	515	61	1152	604	541	514	60	1152	604	541	514	59	1151	604	541	514	
5	62	1150	605	542	516	61	1149	605	543	516	60	1149	606	543	516	59	1148	606	543	516	58	1147	606	543	516	
6	61	1147	607	544	518	60	1146	607	544	518	59	1145	608	545	518	58	1144	608	545	518	57	1143	609	545	518	
7	60	1143	608	546	520	59	1142	609	546	520	58	1141	609	546	520	57	1140	610	547	520	56	1139	611	547	520	
8	59	1140	610	547	521	58	1139	611	548	521	57	1137	611	548	522	56	1136	612	549	522	55	1135	613	549	522	
9	58	1137	612	549	523	57	1135	612	550	523	56	1134	613	550	524	55	1132	614	551	524	54	1131	615	551	524	
10	57	1133	613	551	524	56	1131	614	551	525	55	1130	615	552	525	54	1128	616	553	526	53	1126	617	553	526	
11	56	1130	615	552	526	55	1128	616	553	527	54	1126	617	554	527	53	1124	618	555	528	52	1122	619	555	528	
12	55	1126	617	554	528	54	1124	618	555	528	53	1122	619	556	529	52	1120	620	557	529	51	1118	621	557	530	
13	54	1122	619	556	529	53	1120	620	557	530	52	1118	621	558	531	51	1116	622	558	531	50	1114	623	559	532	
14	53	1119	621	557	531	52	1117	622	558	532	51	1114	623	559	532	50	1112	624	600	533	49	1109	625	601	534	
15	52	1115	622	559	532	51	1113	624	600	533	50	1110	625	601	534	49	1108	626	602	535	48	1105	627	603	536	
16	51	1112	624	601	534	50	1109	626	602	535	49	1106	627	603	536	48	1103	628	604	537	47	1101	630	606	538	
17	50	1108	626	603	536	49	1105	627	604	537	48	1102	629	605	538	47	1059	630	606	539	46	1056	632	608	540	
18	49	1104	628	604	537	48	1101	629	606	538	47	1058	631	607	539	46	1055	633	608	541	45	1052	634	610	542	
19	48	1100	630	606	539	47	1057	631	607	540	46	1054	633	609	541	45	1051	635	610	542	44	1047	636	612	544	
20	47	1057	632	608	540	46	1053	633	609	542	45	1050	635	611	543	44	1046	637	612	544	43	1043	639	614	546	
21	46	1053	634	609	542	45	1049	635	611	543	44	1046	637	613	545	43	1042	639	614	546	42	1038	641	616	548	
22	45	1049	636	611	543	44	1045	637	613	545	43	1041	639	615	546	42	1037	641	616	548	41	1033	643	618	549	
23	44	1045	638	613	545	43	1041	640	615	547	42	1037	642	617	548	41	1033	644	619	550	40	1028	646	620	551	
23.5	44	1043	639	614	546	43	1039	641	616	547	42	1035	643	618	549	41	1030	645	620	551	40	1026	647	621	552	

Table 2, Latitude and Declination SAME

DEC	LAT.28					LAT.29					LAT.30					LAT.31					LAT.32				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
	o	h	m	h	m	h	m	h	m	h	m	o	h	m	h	m	h	m	h	m	h	m	h	m	h
0	62	1208	556	533	506	61	1208	556	533	505	60	1208	556	532	504	59	1208	556	532	504	58	1208	556	532	503
1	63	1212	554	531	503	62	1212	554	530	503	61	1212	554	530	502	60	1213	554	530	501	59	1213	554	529	501
2	64	1216	552	528	501	63	1217	552	528	500	62	1217	552	528	500	61	1217	551	527	459	60	1218	551	527	458
3	65	1220	550	526	459	64	1221	550	526	458	63	1222	549	525	457	62	1222	549	525	456	61	1223	549	524	455
4	66	1225	548	524	457	65	1225	547	524	456	64	1226	547	523	455	63	1227	546	522	454	62	1228	546	521	453
5	67	1229	546	522	454	66	1230	545	521	453	65	1231	545	520	452	64	1232	544	520	451	63	1233	544	519	450
6	68	1233	543	520	452	67	1234	543	519	451	66	1236	542	518	450	65	1237	542	517	448	64	1238	541	516	447
7	69	1238	541	517	450	68	1239	541	517	448	67	1240	540	516	447	66	1242	539	515	446	65	1243	538	514	444
8	70	1242	539	515	447	69	1243	538	514	446	68	1245	537	513	444	67	1247	537	512	443	66	1248	536	511	442
9	71	1246	537	513	445	70	1248	536	512	443	69	1250	535	511	442	68	1252	534	509	440	67	1253	533	508	439
10	72	1251	535	511	442	71	1253	534	509	441	70	1255	533	508	439	69	1257	532	507	438	68	1259	531	506	436
11	73	1255	532	508	440	72	1257	531	507	438	71	1259	530	506	436	70	1302	529	504	435	69	1304	528	503	433
12	74	1300	530	506	437	73	1302	529	504	435	72	1304	528	503	434	71	1307	527	502	432	70	1309	525	500	430
13	75	1304	528	503	435	74	1307	527	502	433	73	1309	525	500	431	72	1312	524	459	429	71	1315	523	457	427
14	76	1309	526	501	432	75	1311	524	459	430	74	1314	523	458	428	73	1317	521	456	426	72	1320	520	454	424
15	77	1313	523	459	429	76	1316	522	457	427	75	1319	520	455	425	74	1322	519	453	423	73	1325	517	451	420
16	78	1318	521	456	426	77	1321	519	454	424	76	1324	518	452	422	75	1328	516	450	419	74	1331	515	448	417
17	79	1323	519	453	423	78	1326	517	452	421	77	1330	515	450	419	76	1333	514	447	416	75	1336	512	445	414
18	80	1328	516	451	421	79	1331	514	449	418	78	1335	513	447	416	77	1338	511	445	413	76	1342	509	442	410
19	81	1333	514	448	418	80	1336	512	446	415	79	1340	510	444	412	78	1344	508	441	410	77	1348	506	439	407
20	82	1337	511	445	415	81	1341	509	443	412	80	1345	507	441	409	79	1350	505	438	406	78	1354	503	436	403
21	83	1342	509	443	411	82	1347	507	440	409	81	1351	505	438	406	80	1355	502	435	403	79	1400	500	433	359
22	84	1348	506	440	408	83	1352	504	437	405	82	1356	502	435	402	81	1401	459	432	359	80	1406	457	429	356
23	85	1353	504	437	405	84	1357	501	434	402	83	1402	459	432	358	82	1407	457	429	355	81	1412	454	426	352
23.5	86	1355	502	436	403	85	1400	500	433	400	84	1405	457	430	357	83	1410	455	427	353	82	1415	452	424	350

Latitude and Declination OPPOSITE

	LAT.28					LAT.29					LAT.30					LAT.31					LAT.32								
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT				
o	o	h	m	h	m	h	m	h	m	h	o	h	m	h	m	h	o	h	m	h	m	h	o	h	m	h	m	h	m
0	62	1208	556	533	506	61	1208	556	533	505	60	1208	556	532	504	59	1208	556	532	504	58	1208	556	532	503				
1	61	1203	558	535	508	60	1203	558	535	507	59	1203	558	535	507	58	1203	559	534	506	57	1203	559	534	506				
2	60	1159	600	537	510	59	1159	601	537	510	58	1158	601	537	509	57	1158	601	537	509	56	1158	601	537	508				
3	59	1155	603	539	512	58	1154	603	539	512	57	1154	603	539	511	56	1153	603	539	511	55	1153	604	539	511				
4	58	1151	605	541	514	57	1150	605	541	514	56	1149	605	542	514	55	1149	606	542	514	54	1148	606	542	513				
5	57	1146	607	543	516	56	1145	607	544	516	55	1145	608	544	516	54	1144	608	544	516	53	1143	609	544	516				
6	56	1142	609	546	518	55	1141	610	546	518	54	1140	610	546	518	53	1139	611	546	518	52	1138	611	547	518				
7	55	1138	611	548	520	54	1136	612	548	521	53	1135	612	548	521	52	1134	613	549	521	51	1133	614	549	521				
8	54	1133	613	550	522	53	1132	614	550	523	52	1131	615	551	523	51	1129	615	551	523	50	1128	616	552	523				
9	53	1129	615	552	525	52	1127	616	552	525	51	1126	617	553	525	50	1124	618	554	525	49	1123	619	554	526				
10	52	1125	618	554	527	51	1123	619	555	527	50	1121	619	555	527	49	1119	620	556	528	48	1117	621	557	528				
11	51	1120	620	556	529	50	1118	621	557	529	49	1116	622	558	530	48	1114	623	558	530	47	1112	624	559	531				
12	50	1116	622	558	531	49	1114	623	559	531	48	1112	624	600	532	47	1109	625	601	532	46	1107	626	602	533				
13	49	1111	624	600	533	48	1109	625	601	533	47	1107	627	602	534	46	1104	628	603	535	45	1102	629	604	535				
14	48	1107	627	602	535	47	1104	628	603	535	46	1102	629	604	536	45	1059	630	606	537	44	1056	632	607	538				
15	47	1102	629	605	537	46	1100	630	606	538	45	1057	632	607	538	44	1054	633	608	539	43	1051	634	609	540				
16	46	1058	631	607	539	45	1055	633	608	540	44	1052	634	609	541	43	1049	636	610	542	42	1046	637	612	543				
17	45	1053	633	609	541	44	1050	635	610	542	43	1047	637	612	543	42	1044	638	613	544	41	1040	640	614	545				
18	44	1048	636	611	543	43	1045	637	612	544	42	1042	639	614	545	41	1038	641	615	546	40	1035	643	617	547				
19	43	1044	638	613	545	42	1040	640	615	546	41	1037	642	616	547	40	1033	644	618	549	39	1029	645	619	550				
20	42	1039	641	615	547	41	1035	642	617	548	40	1031	644	619	550	39	1027	646	620	551	38	1023	648	622	552				
21	41	1034	643	618	549	40	1030	645	619	550	39	1026	647	621	552	38	1022	649	623	553	37	1018	651	625	555				
22	40	1029	645	620	551	39	1025	648	622	553	38	1021	650	624	554	37	1016	652	626	556	36	1012	654	627	557				
23	39	1024	648	622	553	38	1020	650	624	555	37	1015	652	626	556	36	1011	655	628	558	35	1006	657	630	600				
23.5	39	1022	649	623	554	38	1017	652	625	556	37	1012	654	627	558	36	1008	656	629	559	35	1003	659	632	601				

Table 2, Latitude and Declination SAME

DEC	LAT.33					LAT.34					LAT.35					LAT.36					LAT.37				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
0	o	h	m	h	m	h	m	h	m	h	m	o	h	m	h	m	h	m	h	m	h	h	m	h	m
0	57	1208	556	531	503	56	1208	556	531	502	55	1208	556	531	501	54	1208	556	530	500	53	1208	556	530	500
1	58	1213	553	529	500	57	1213	553	528	459	56	1214	553	528	458	55	1214	553	527	457	54	1214	553	527	457
2	59	1218	551	526	457	58	1219	551	526	456	57	1219	550	525	455	56	1220	550	524	454	55	1220	550	524	453
3	60	1224	548	523	454	59	1224	548	523	453	58	1225	548	522	452	57	1226	547	521	451	56	1226	547	521	450
4	61	1229	546	521	452	60	1230	545	520	451	59	1231	545	519	449	58	1232	544	518	448	57	1233	544	518	447
5	62	1234	543	518	449	61	1235	542	517	448	60	1236	542	516	446	59	1237	541	515	445	58	1239	541	514	444
6	63	1239	540	515	446	62	1241	540	514	445	61	1242	539	513	443	60	1243	538	512	442	59	1245	538	511	440
7	64	1245	538	513	443	63	1246	537	512	442	62	1248	536	510	440	61	1249	535	509	439	60	1251	535	508	437
8	65	1250	535	510	440	64	1252	534	509	439	63	1253	533	507	437	62	1255	532	506	435	61	1257	531	505	433
9	66	1255	532	507	437	65	1257	531	506	435	64	1259	530	504	434	63	1301	529	503	432	62	1303	528	502	430
10	67	1301	530	504	434	66	1303	529	503	432	65	1305	527	501	430	64	1307	526	500	428	63	1310	525	458	426
11	68	1306	527	501	431	67	1309	526	500	429	66	1311	525	458	427	65	1313	523	457	425	64	1316	522	455	423
12	69	1312	524	458	428	68	1314	523	457	426	67	1317	522	455	424	66	1320	520	453	421	65	1322	519	452	419
13	70	1317	521	455	425	69	1320	520	454	422	68	1323	519	452	420	67	1326	517	450	418	66	1329	516	448	415
14	71	1323	519	452	421	70	1326	517	451	419	69	1329	516	449	417	68	1332	514	447	414	67	1335	512	445	411
15	72	1329	516	449	418	71	1332	514	447	415	70	1335	512	445	413	69	1339	511	443	410	68	1342	509	441	407
16	73	1334	513	446	415	72	1338	511	444	412	71	1341	509	442	409	70	1345	508	440	406	69	1349	506	438	403
17	74	1340	510	443	411	73	1344	508	441	408	72	1348	506	439	405	71	1352	504	436	402	70	1356	502	434	359
18	75	1346	507	440	407	74	1350	505	438	405	73	1354	503	435	401	72	1358	501	433	358	71	1402	459	430	355
19	76	1352	504	437	404	75	1356	502	434	401	74	1401	500	432	357	73	1405	458	429	354	72	1409	455	426	351
20	77	1358	501	433	400	76	1403	459	431	357	75	1407	456	428	353	74	1412	454	425	350	73	1417	452	422	346
21	78	1404	458	430	356	77	1409	456	427	353	76	1414	453	424	349	75	1419	451	421	345	74	1424	448	418	342
22	79	1411	455	426	352	78	1416	452	424	348	77	1421	450	421	345	76	1426	447	417	341	75	1431	444	414	337
23	80	1417	451	423	348	79	1422	449	420	344	78	1428	446	417	340	77	1433	443	413	336	76	1439	441	410	332
23.5	81	1420	450	421	346	80	1426	447	418	342	79	1431	444	415	338	78	1437	442	411	334	77	1443	439	408	329

Latitude and Declination OPPOSITE

DEC	LAT.33					LAT.34					LAT.35					LAT.36					LAT.37				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
0	o	h	m	h	m	h	m	h	m	h	m	o	h	m	h	m	h	m	h	m	h	h	m	h	m
0	57	1208	556	531	503	56	1208	556	531	502	55	1208	556	531	501	54	1208	556	530	500	53	1208	556	530	500
1	56	1203	559	534	505	55	1203	559	534	505	54	1203	559	533	504	53	1202	559	533	503	52	1202	559	533	503
2	55	1158	601	537	508	54	1157	601	536	507	53	1157	602	536	507	52	1157	602	536	506	51	1156	602	536	506
3	54	1152	604	539	511	53	1152	604	539	510	52	1151	604	539	510	51	1151	605	539	509	50	1150	605	539	509
4	53	1147	606	542	513	52	1146	607	542	513	51	1146	607	542	513	50	1145	608	542	512	49	1144	608	542	512
5	52	1142	609	544	516	51	1141	609	545	516	50	1140	610	545	515	49	1139	610	545	515	48	1138	611	545	515
6	51	1137	612	547	518	50	1136	612	547	518	49	1134	613	547	518	48	1133	613	548	518	47	1132	614	548	518
7	50	1131	614	549	521	49	1130	615	550	521	48	1129	616	550	521	47	1127	616	551	521	46	1126	617	551	521
8	49	1126	617	552	523	48	1125	618	553	524	47	1123	618	553	524	46	1121	619	553	524	45	1120	620	554	524
9	48	1121	620	555	526	47	1119	620	555	526	46	1117	621	556	526	45	1116	622	556	527	44	1114	623	557	527
10	47	1116	622	557	528	46	1114	623	558	529	45	1112	624	559	529	44	1110	625	559	529	43	1107	626	600	530
11	46	1110	625	600	531	45	1108	626	601	531	44	1106	627	601	532	43	1104	628	602	532	42	1101	629	603	533
12	45	1105	628	602	533	44	1102	629	603	534	43	1100	630	604	535	42	1057	631	605	535	41	1055	633	606	536
13	44	1059	630	605	536	43	1057	632	606	537	42	1054	633	607	537	41	1051	634	608	538	40	1049	636	609	539
14	43	1054	633	608	539	42	1051	635	609	539	41	1048	636	610	540	40	1045	637	611	541	39	1042	639	612	542
15	42	1048	636	610	541	41	1045	637	612	542	40	1042	639	613	543	39	1039	641	614	544	38	1036	642	615	544
16	41	1043	639	613	544	40	1039	640	614	545	39	1036	642	616	545	38	1033	644	617	546	37	1029	645	618	547
17	40	1037	642	616	546	39	1033	643	617	547	38	1030	645	619	548	37	1026	647	620	549	36	1022	649	621	550
18	39	1031	644	618	549	38	1027	646	620	550	37	1024	648	621	551	36	1020	650	623	552	35	1016	652	625	553
19	38	1025	647	621	551	37	1021	649	623	552	36	1017	651	624	554	35	1013	653	626	555	34	1009	656	628	556
20	37	1019	650	624	554	36	1015	652	626	555	35	1011	655	627	557	34	1006	657	629	558	33	1002	659	631	559
21	36	1013	653	627	556	35	1009	656	628	558	34	1004	658	630	559	33	1000	700	632	601	32	955	703	634	602
22	35	1007	656	629	559	34	1002	659	631	600	33	958	701	633	602	32	953	704	635	604	31	948	706	638	605
23	34	1001	700	632	601	33	956	702	634	603	32	951	705	637	605	31	946	707	639	607	30	940	710	641	608
23.5	34	958	701	634	603	33	953	704	636	605	32	947	706	638	606	31	942	709	640	608	30	937	712	643	610

Table 2, Latitude and Declination SAME

DEC	LAT.38					LAT.39					LAT.40					LAT.41					LAT.42				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
	o	h	m	h	m	o	h	m	h	m	o	h	m	h	m	o	h	m	h	m	o	h	m	h	m
0	52	1208	556	530	459	51	1209	556	529	458	50	1209	556	529	457	49	1209	556	528	456	48	1209	556	528	455
1	53	1215	553	526	456	52	1215	552	526	455	51	1215	552	525	454	50	1216	552	525	452	49	1216	552	524	451
2	54	1221	550	523	452	53	1222	549	523	451	52	1222	549	522	450	51	1223	549	521	449	50	1223	548	520	447
3	55	1227	546	520	449	54	1228	546	519	448	53	1229	546	518	446	52	1230	545	518	445	51	1231	545	517	444
4	56	1234	543	517	446	55	1235	543	516	444	54	1236	542	515	443	53	1237	542	514	441	52	1238	541	513	440
5	57	1240	540	513	442	56	1241	539	512	441	55	1242	539	511	439	54	1244	538	510	437	53	1245	537	509	436
6	58	1246	537	510	439	57	1248	536	509	437	56	1249	535	508	435	55	1251	535	507	434	54	1253	534	505	432
7	59	1253	534	507	435	58	1254	533	506	433	57	1256	532	504	432	56	1258	531	503	430	55	1300	530	502	428
8	60	1259	530	504	432	59	1301	529	502	430	58	1303	528	501	428	57	1305	527	459	426	56	1307	526	458	423
9	61	1306	527	500	428	60	1308	526	459	426	59	1310	525	457	424	58	1312	524	455	422	57	1315	523	454	419
10	62	1312	524	457	424	61	1314	523	455	422	60	1317	521	453	420	59	1320	520	452	417	58	1322	519	450	415
11	63	1319	521	453	420	62	1321	519	452	418	61	1324	518	450	416	60	1327	517	448	413	59	1330	515	446	410
12	64	1325	517	450	417	63	1328	516	448	414	62	1331	514	446	412	61	1334	513	444	409	60	1338	511	442	406
13	65	1332	514	446	413	64	1335	512	444	410	63	1338	511	442	407	62	1342	509	440	404	61	1345	507	438	401
14	66	1339	511	443	409	65	1342	509	440	406	64	1346	507	438	403	63	1349	505	436	400	62	1353	503	433	357
15	67	1346	507	439	405	66	1349	505	437	402	65	1353	503	434	358	64	1357	501	432	355	63	1401	459	429	352
16	68	1353	504	435	400	67	1357	502	433	357	66	1401	500	430	354	65	1405	458	427	350	64	1409	455	425	347
17	69	1400	500	431	356	68	1404	458	429	353	67	1408	456	426	349	66	1413	454	423	345	65	1418	451	420	342
18	70	1407	457	427	352	69	1411	454	425	348	68	1416	452	422	344	67	1421	450	419	340	66	1426	447	415	336
19	71	1414	453	423	347	70	1419	451	420	343	69	1424	448	417	339	68	1429	445	414	335	67	1435	443	411	331
20	72	1422	449	419	342	71	1427	447	416	338	70	1432	444	413	334	69	1438	441	409	330	68	1443	438	406	325
21	73	1429	445	415	337	72	1435	443	412	333	71	1440	440	408	329	70	1446	437	405	324	69	1452	434	401	319
22	74	1437	442	411	332	73	1443	439	407	328	72	1449	436	404	323	71	1455	433	400	318	70	1501	429	356	313
23	75	1445	438	406	327	74	1451	435	403	323	73	1457	431	359	318	72	1504	428	355	312	71	1510	425	351	307
23.5	76	1449	436	404	325	75	1455	433	400	320	74	1501	429	356	315	73	1508	426	352	309	72	1515	422	348	303

Latitude and Declination OPPOSITE

DEC	LAT.38					LAT.39					LAT.40					LAT.41					LAT.42				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
	o	h	m	h	m	h	m	h	m	h	m	o	h	m	h	m	h	m	h	m	h	m	h	m	h
0	52	1208	556	530	459	51	1209	556	529	458	50	1209	556	529	457	49	1209	556	528	456	48	1209	556	528	455
1	51	1202	559	533	502	50	1202	559	532	501	49	1202	559	532	500	48	1202	559	532	500	47	1202	559	531	459
2	50	1156	602	536	505	49	1156	602	536	505	48	1155	602	535	504	47	1155	603	535	503	46	1155	603	535	502
3	49	1150	605	539	508	48	1149	605	539	508	47	1149	606	539	507	46	1148	606	539	507	45	1147	606	539	506
4	48	1143	608	542	512	47	1143	609	542	511	46	1142	609	542	511	45	1141	610	542	510	44	1140	610	542	510
5	47	1137	611	545	515	46	1136	612	545	514	45	1135	612	545	514	44	1134	613	546	514	43	1133	614	546	513
6	46	1131	615	548	518	45	1130	615	549	518	44	1128	616	549	517	43	1127	617	549	517	42	1126	617	549	517
7	45	1125	618	551	521	44	1123	618	552	521	43	1121	619	552	521	42	1120	620	552	521	41	1118	621	553	521
8	44	1118	621	554	524	43	1116	622	555	524	42	1115	623	555	524	41	1113	624	556	524	40	1111	625	556	524
9	43	1112	624	558	527	42	1110	625	558	527	41	1108	626	559	527	40	1106	627	559	528	39	1104	628	600	528
10	42	1105	627	601	530	41	1103	628	601	530	40	1101	630	602	531	39	1059	631	603	531	38	1056	632	604	531
11	41	1059	631	604	533	40	1056	632	605	534	39	1054	633	606	534	38	1051	634	606	534	37	1049	636	607	535
12	40	1052	634	607	536	39	1050	635	608	537	38	1047	637	609	537	37	1044	638	610	538	36	1041	639	611	538
13	39	1046	637	610	539	38	1043	639	611	540	37	1040	640	612	541	36	1037	642	613	541	35	1033	643	615	542
14	38	1039	640	613	542	37	1036	642	615	543	36	1033	644	616	544	35	1029	645	617	545	34	1026	647	618	545
15	37	1032	644	617	545	36	1029	646	618	546	35	1025	647	619	547	34	1022	649	621	548	33	1018	651	622	549
16	36	1025	647	620	548	35	1022	649	621	549	34	1018	651	623	550	33	1014	653	624	551	32	1010	655	626	552
17	35	1019	651	623	552	34	1015	653	625	553	33	1010	655	626	554	32	1006	657	628	555	31	1002	659	629	556
18	34	1012	654	626	555	33	1007	656	628	556	32	1003	659	630	557	31	958	701	631	558	30	954	703	633	600
19	33	1004	658	630	558	32	1000	700	631	559	31	955	702	633	600	30	950	705	635	602	29	945	707	637	603
20	32	957	701	633	601	31	952	704	635	602	30	947	706	637	604	29	942	709	639	605	28	937	711	641	607
21	31	950	705	636	604	30	945	708	638	606	29	939	710	641	607	28	934	713	643	609	27	928	716	645	611
22	30	942	709	640	607	29	937	712	642	609	28	931	714	644	611	27	926	717	647	612	26	920	720	649	614
23	29	935	713	643	610	28	929	715	646	612	27	923	718	648	614	26	917	721	650	616	25	911	725	653	618
23.5	29	931	715	645	612	28	925	717	647	614	27	919	721	650	616	26	913	724	652	618	25	906	727	655	620

Table 2, Latitude and Declination SAME

	LAT.43					LAT.44					LAT.45					LAT.46					LAT.47					
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	
o	o	h	m	h	m	h	m	h	m	h	o	h	m	h	m	h	o	h	m	h	m	o	h	m	h	m
0	47	1209	555	527	454	46	1209	555	527	453	45	1209	555	526	452	44	1210	555	525	450	43	1210	555	525	449	
1	48	1217	552	523	450	47	1217	552	523	449	46	1217	551	522	447	45	1218	551	521	446	44	1218	551	520	444	
2	49	1224	548	520	446	48	1225	548	519	445	47	1225	547	518	443	46	1226	547	517	442	45	1227	547	516	440	
3	50	1232	544	516	442	49	1233	544	515	440	48	1233	543	514	439	47	1235	543	513	437	46	1236	542	512	435	
4	51	1239	540	512	438	50	1240	540	511	436	49	1242	539	510	434	48	1243	539	508	433	47	1244	538	507	431	
5	52	1247	537	508	434	51	1248	536	507	432	50	1250	535	505	430	49	1251	534	504	428	48	1253	534	503	426	
6	53	1254	533	504	430	52	1256	532	503	428	51	1258	531	501	425	50	1300	530	500	423	49	1302	529	458	421	
7	54	1302	529	500	425	53	1304	528	459	423	52	1306	527	457	421	51	1308	526	455	418	50	1310	525	454	416	
8	55	1310	525	456	421	54	1312	524	454	419	53	1314	523	453	416	52	1317	522	451	414	51	1319	520	449	411	
9	56	1317	521	452	417	55	1320	520	450	414	54	1323	519	448	411	53	1325	517	446	409	52	1328	516	444	406	
10	57	1325	517	448	412	56	1328	516	446	409	55	1331	515	444	407	54	1334	513	442	404	53	1337	511	439	400	
11	58	1333	513	444	408	57	1336	512	442	405	56	1339	510	439	402	55	1343	509	437	358	54	1346	507	434	355	
12	59	1341	510	439	403	58	1344	508	437	400	57	1348	506	435	357	56	1352	504	432	353	55	1356	502	430	349	
13	60	1349	505	435	358	59	1353	504	433	355	58	1357	502	430	351	57	1401	500	427	348	56	1405	457	424	344	
14	61	1357	501	431	353	60	1401	459	428	350	59	1406	457	425	346	58	1410	455	422	342	57	1415	453	419	338	
15	62	1406	457	426	348	61	1410	455	423	344	60	1415	453	420	340	59	1419	450	417	336	58	1424	448	414	332	
16	63	1414	453	422	343	62	1419	451	419	339	61	1424	448	415	335	60	1429	446	412	330	59	1434	443	409	325	
17	64	1422	449	417	338	63	1428	446	414	333	62	1433	444	410	329	61	1438	441	407	324	60	1444	438	403	319	
18	65	1431	444	412	332	64	1437	442	409	327	63	1442	439	405	323	62	1448	436	401	317	61	1454	433	357	312	
19	66	1440	440	407	326	65	1446	437	404	321	64	1452	434	400	316	63	1458	431	356	311	62	1505	428	352	305	
20	67	1449	435	402	320	66	1455	432	358	315	65	1502	429	354	310	64	1508	426	350	304	63	1515	422	346	258	
21	68	1458	431	357	314	67	1505	428	353	309	66	1512	424	349	303	65	1519	421	344	256	64	1526	417	339	250	
22	69	1508	426	352	308	68	1515	423	347	302	67	1522	419	343	255	66	1529	415	338	249	65	1537	411	333	241	
23	70	1517	421	346	301	69	1525	418	342	254	68	1532	414	337	248	67	1540	410	332	240	66	1549	406	326	233	
23.5	71	1522	419	343	257	70	1530	415	339	251	69	1538	411	334	244	68	1546	407	328	236	67	1554	403	323	228	

Latitude and Declination OPPOSITE

	LAT.43					LAT.44					LAT.45					LAT.46					LAT.47					
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	
o	o	h	m	h	m	h	m	o	h	m	h	m	h	m	o	h	m	o	h	m	h	o	h	m	h	m
0	47	1209	555	527	454	46	1209	555	527	453	45	1209	555	526	452	44	1210	555	525	450	43	1210	555	525	449	
1	46	1202	559	531	458	45	1202	559	530	457	44	1201	559	530	456	43	1201	559	530	455	42	1201	559	529	453	
2	45	1154	603	535	502	44	1154	603	534	501	43	1153	603	534	500	42	1153	603	534	459	41	1153	604	533	458	
3	44	1147	607	538	505	43	1146	607	538	505	42	1145	607	538	504	41	1145	608	538	503	40	1144	608	538	502	
4	43	1139	610	542	509	42	1138	611	542	509	41	1137	611	542	508	40	1136	612	542	507	39	1135	612	542	507	
5	42	1132	614	546	513	41	1131	615	546	513	40	1129	615	546	512	39	1128	616	546	512	38	1127	617	546	511	
6	41	1124	618	550	517	40	1123	619	550	516	39	1121	619	550	516	38	1120	620	550	516	37	1118	621	551	515	
7	40	1117	622	553	520	39	1115	623	554	520	38	1113	623	554	520	37	1111	624	554	520	36	1109	625	555	520	
8	39	1109	625	557	524	38	1107	626	557	524	37	1105	628	558	524	36	1103	629	559	524	35	1101	630	559	524	
9	38	1101	629	601	528	37	1059	630	601	528	36	1057	632	602	528	35	1054	633	603	528	34	1052	634	603	528	
10	37	1054	633	604	531	36	1051	634	605	532	35	1048	636	606	532	34	1046	637	607	532	33	1043	639	608	532	
11	36	1046	637	608	535	35	1043	638	609	535	34	1040	640	610	536	33	1037	641	611	536	32	1034	643	612	537	
12	35	1038	641	612	539	34	1035	643	613	539	33	1032	644	614	540	32	1028	646	615	540	31	1025	648	616	541	
13	34	1030	645	616	542	33	1027	647	617	543	32	1023	648	618	544	31	1019	650	619	544	30	1016	652	621	545	
14	33	1022	649	620	546	32	1018	651	621	547	31	1015	653	622	548	30	1011	655	624	548	29	1006	657	625	549	
15	32	1014	653	623	550	31	1010	655	625	551	30	1006	657	626	552	29	1001	659	628	553	28	957	702	630	554	
16	31	1006	657	627	554	30	1001	659	629	555	29	957	702	631	556	28	952	704	632	557	27	947	706	634	558	
17	30	957	701	631	557	29	953	704	633	558	28	948	706	635	600	27	943	709	637	601	26	938	711	639	602	
18	29	949	706	635	601	28	944	708	637	602	27	939	711	639	604	26	933	713	641	605	25	928	716	643	606	
19	28	940	710	639	605	27	935	713	641	606	26	929	715	643	608	25	924	718	646	609	24	918	721	648	611	
20	27	932	714	643	608	26	926	717	645	610	25	920	720	648	612	24	914	723	650	613	23	907	726	653	615	
21	26	923	719	647	612	25	917	722	650	614	24	910	725	652	616	23	904	728	655	618	22	857	732	657	620	
22	25	913	723	651	616	24	907	726	654	618	23	900	730	657	620	22	853	733	659	622	21	846	737	702	624	
23	24	904	728	656	620	23	857	731	658	622	22	850	735	701	624	21	843	739	704	626	20	835	742	707	628	
23.5	24	859	730	658	622	23	852	734	701	624	22	845	737	704	626	21	838	741	707	628	20	830	745	710	631	

Table 2, Latitude and Declination SAME

DEC	LAT.48					LAT.49					LAT.50					LAT.51					LAT.52				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
0	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	42	1210	555	524	448	41	1210	555	523	446	40	1210	555	523	445	39	1211	555	522	443	38	1211	555	521	441
1	43	1219	551	520	443	42	1219	550	519	441	41	1220	550	518	439	40	1220	550	517	438	39	1221	549	516	436
2	44	1228	546	515	438	43	1229	546	514	436	42	1229	545	513	434	41	1230	545	512	432	40	1231	544	510	430
3	45	1237	542	510	433	44	1238	541	509	431	43	1239	540	508	429	42	1240	540	507	427	41	1242	539	505	424
4	46	1246	537	506	428	45	1247	536	504	426	44	1249	536	503	424	43	1250	535	501	421	42	1252	534	500	419
5	47	1255	533	501	423	46	1256	532	500	421	45	1258	531	458	418	44	1300	530	456	416	43	1302	529	454	413
6	48	1304	528	456	418	47	1306	527	455	416	46	1308	526	453	413	45	1310	525	451	410	44	1313	524	449	407
7	49	1313	524	452	413	48	1315	522	450	410	47	1318	521	448	407	46	1321	520	446	404	45	1323	518	443	401
8	50	1322	519	447	408	49	1325	518	445	405	48	1328	516	443	402	47	1331	515	440	358	46	1334	513	438	354
9	51	1331	514	442	403	50	1334	513	440	359	49	1338	511	437	356	48	1341	509	435	352	47	1345	508	432	348
10	52	1341	510	437	357	51	1344	508	434	353	50	1348	506	432	350	49	1352	504	429	346	48	1356	502	426	341
11	53	1350	505	432	351	52	1354	503	429	348	51	1358	501	426	343	50	1402	459	423	339	49	1407	457	420	335
12	54	1400	500	427	346	53	1404	458	424	341	52	1408	456	421	337	51	1413	453	418	332	50	1418	451	414	328
13	55	1409	455	421	340	54	1414	453	418	335	53	1419	451	415	330	52	1424	448	412	326	51	1429	445	408	320
14	56	1419	450	416	333	55	1424	448	413	329	54	1430	445	409	324	53	1435	443	405	318	52	1441	440	402	313
15	57	1429	445	411	327	56	1435	443	407	322	55	1440	440	403	317	54	1446	437	359	311	53	1452	434	355	305
16	58	1440	440	405	320	57	1445	437	401	315	56	1451	434	357	309	55	1458	431	353	303	54	1504	428	348	256
17	59	1450	435	359	313	58	1456	432	355	308	57	1503	429	351	301	56	1509	425	346	255	55	1517	422	341	248
18	60	1501	430	353	306	59	1507	426	349	300	58	1514	423	344	253	57	1521	419	339	246	56	1529	415	334	238
19	61	1511	424	347	259	60	1518	421	342	252	59	1526	417	338	245	58	1534	413	332	237	57	1542	409	327	228
20	62	1522	419	341	251	61	1530	415	336	244	60	1538	411	331	236	59	1546	407	325	227	58	1555	402	319	218
21	63	1534	413	334	242	62	1542	409	329	235	61	1550	405	323	226	60	1559	400	317	216	59	1609	356	311	206
22	64	1545	407	328	234	63	1554	403	322	225	62	1603	358	316	215	61	1613	354	309	205	60	1623	349	302	153
23	65	1557	401	320	224	64	1607	357	314	215	63	1616	352	308	204	62	1627	347	301	152	61	1637	341	253	138
23.5	66	1604	358	317	219	65	1613	353	311	209	64	1623	348	304	158	63	1634	343	256	145	62	1645	338	249	129

Latitude and Declination OPPOSITE

DEC	LAT.48					LAT.49					LAT.50					LAT.51					LAT.52				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
0	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	42	1210	555	524	448	41	1210	555	523	446	40	1210	555	523	445	39	1211	555	522	443	38	1211	555	521	441
1	41	1201	559	529	452	40	1201	600	528	451	39	1201	600	527	450	38	1201	600	527	448	37	1201	600	526	446
2	40	1152	604	533	457	39	1152	604	533	456	38	1151	604	532	454	37	1151	605	532	453	36	1150	605	531	452
3	39	1143	608	537	501	38	1143	609	537	500	37	1142	609	537	459	36	1141	610	537	458	35	1140	610	536	457
4	38	1134	613	542	506	37	1133	613	542	505	36	1132	614	542	504	35	1131	614	542	503	34	1130	615	541	502
5	37	1125	617	546	510	36	1124	618	546	510	35	1123	619	546	509	34	1121	619	547	508	33	1119	620	547	508
6	36	1116	622	551	515	35	1115	623	551	514	34	1113	624	551	514	33	1111	624	551	513	32	1109	625	552	513
7	35	1107	626	555	519	34	1105	627	556	519	33	1103	628	556	519	32	1101	629	556	518	31	1059	631	557	518
8	34	1058	631	600	524	33	1056	632	600	524	32	1053	633	601	523	31	1051	635	601	523	30	1048	636	602	523
9	33	1049	635	604	528	32	1046	637	605	528	31	1044	638	606	528	30	1041	640	606	528	29	1038	641	607	528
10	32	1040	640	609	533	31	1037	642	609	533	30	1034	643	610	533	29	1030	645	611	533	28	1027	647	612	533
11	31	1031	645	613	537	30	1027	646	614	537	29	1024	648	615	538	28	1020	650	616	538	27	1016	652	617	538
12	30	1021	649	618	541	29	1017	651	619	542	28	1014	653	620	542	27	1009	655	621	543	26	1005	657	623	543
13	29	1012	654	622	546	28	1008	656	623	546	27	1003	658	625	547	26	959	701	626	548	25	954	703	628	548
14	28	1002	659	627	550	27	958	701	628	551	26	953	704	630	552	25	948	706	631	553	24	943	709	633	553
15	27	952	704	631	554	26	947	706	633	555	25	942	709	635	556	24	937	712	637	557	23	931	714	638	558
16	26	942	709	636	559	25	937	711	638	600	24	932	714	640	601	23	926	717	642	602	22	920	720	644	604
17	25	932	714	641	603	24	927	717	643	605	23	921	720	645	606	22	914	723	647	607	21	908	726	649	609
18	24	922	719	645	608	23	916	722	648	609	22	910	725	650	611	21	903	729	652	612	20	856	732	655	614
19	23	911	724	650	612	22	905	728	653	614	21	858	731	655	616	20	851	735	658	617	19	843	738	701	619
20	22	901	730	655	617	21	854	733	658	619	20	847	737	700	621	19	839	741	703	622	18	831	745	706	624
21	21	850	735	700	621	20	842	739	703	623	19	835	743	706	625	18	826	747	709	628	17	818	751	712	630
22	20	839	741	705	626	19	831	745	708	628	18	822	749	711	630	17	814	753	715	633	16	804	758	718	635
23	19	827	746	710	631	18	819	751	713	633	17	810	755	717	636	16	800	800	720	638	15	751	805	724	641
23.5	19	821	749	713	633	18	813	754	716	636	17	803	758	720	638	16	754	803	723	641	15	744	808	727	643

Table 2, Latitude and Declination SAME

DEC o	LAT.53					LAT.54					LAT.55					LAT.56					LAT.57				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
0	37	1211	554	520	439	36	1211	554	519	437	35	1212	554	518	435	34	1212	554	517	433	33	1212	554	516	430
1	38	1222	549	515	433	37	1222	549	513	431	36	1223	548	512	429	35	1224	548	511	426	34	1225	548	509	424
2	39	1232	544	509	428	38	1233	543	508	425	37	1235	543	506	423	36	1236	542	505	420	35	1237	542	503	417
3	40	1243	538	504	422	39	1244	538	502	419	38	1246	537	500	416	37	1248	536	499	413	36	1249	535	497	410
4	41	1254	533	498	416	40	1256	532	496	413	39	1258	531	494	410	38	1300	530	492	406	37	1302	529	490	403
5	42	1305	528	492	410	41	1307	527	490	406	40	1309	525	488	403	39	1312	524	486	399	38	1314	523	484	395
6	43	1315	522	487	403	42	1318	521	485	400	41	1321	520	482	396	40	1324	518	480	392	39	1327	516	477	388
7	44	1326	517	481	397	43	1329	515	483	393	42	1333	514	478	389	41	1336	512	476	385	40	1340	510	473	380
8	45	1337	511	475	391	44	1341	510	472	386	43	1345	508	470	382	42	1349	506	468	377	41	1353	504	473	382
9	46	1349	506	469	384	45	1353	504	466	379	44	1357	502	462	374	43	1401	499	460	369	42	1406	497	466	374
10	47	1400	500	463	377	46	1404	498	460	372	45	1409	496	458	367	44	1414	493	456	362	43	1419	490	453	361
11	48	1411	494	457	370	47	1416	492	454	366	46	1421	489	452	361	45	1427	487	450	357	44	1432	484	451	356
12	49	1423	489	451	362	48	1428	486	448	361	47	1434	483	446	356	46	1440	480	444	351	45	1446	477	448	347
13	50	1435	483	445	355	49	1441	480	442	350	48	1447	477	440	350	47	1453	474	437	345	46	1500	470	434	342
14	51	1447	477	439	348	50	1453	473	433	343	49	1500	470	430	348	48	1507	467	427	343	47	1514	463	423	338
15	52	1459	471	433	341	51	1506	467	427	338	50	1513	464	424	341	49	1521	460	420	335	48	1529	456	416	329
16	53	1511	465	427	334	52	1519	461	421	333	51	1527	457	417	333	50	1535	452	412	327	49	1544	448	412	321
17	54	1524	459	421	327	53	1532	455	415	326	52	1541	451	410	325	51	1550	447	408	321	50	1559	444	408	315
18	55	1537	453	415	320	54	1546	449	409	320	53	1555	445	402	316	52	1605	440	400	315	51	1615	436	402	309
19	56	1551	447	409	313	55	1600	443	403	314	54	1610	439	400	307	53	1620	435	398	300	52	1632	431	394	294
20	57	1605	441	403	306	56	1615	437	397	305	55	1625	433	392	300	54	1636	427	386	293	53	1649	421	386	287
21	58	1619	435	397	300	57	1630	431	391	299	56	1641	427	386	293	55	1653	421	380	287	54	1706	415	380	281
22	59	1634	429	391	293	58	1645	425	385	292	57	1657	419	380	287	56	1711	415	374	281	55	1725	409	374	275
23	60	1649	423	385	286	59	1701	419	379	286	58	1715	413	374	281	57	1729	409	368	275	56	1744	403	368	269
23.5	61	1657	417	379	280	60	1710	413	373	280	59	1724	407	368	275	58	1738	401	362	269	57	1755	395	362	263

/// = Twilight lasts all night.

Latitude and Declination OPPOSITE

DEC o	LAT.53					LAT.54					LAT.55					LAT.56					LAT.57				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
0	37	1211	554	520	439	36	1211	554	519	437	35	1212	554	518	435	34	1212	554	517	433	33	1212	554	516	430
1	36	1200	600	525	445	35	1200	600	525	443	34	1200	600	524	441	33	1200	600	523	439	32	1200	600	522	437
2	35	1150	605	531	450	34	1149	605	530	449	33	1149	606	530	447	32	1148	606	529	445	31	1148	606	528	443
3	34	1139	610	536	456	33	1138	611	536	454	32	1137	611	535	453	31	1136	612	535	451	30	1135	612	534	450
4	33	1129	616	541	501	32	1127	616	541	500	31	1126	617	541	499	30	1124	618	541	498	29	1123	619	541	496
5	32	1118	621	547	507	31	1116	622	547	506	30	1114	623	547	505	29	1112	624	547	504	28	1110	625	547	502
6	31	1107	626	552	512	30	1105	628	552	511	29	1103	629	552	510	28	1100	630	553	510	27	1058	631	553	509
7	30	1056	632	557	517	29	1054	633	558	517	28	1051	634	558	516	27	1048	636	559	516	26	1045	637	559	515
8	29	1045	637	603	523	28	1042	639	603	522	27	1039	640	604	522	26	1036	642	604	522	25	1033	644	605	521
9	28	1034	643	608	528	27	1031	644	609	528	26	1027	646	610	528	25	1024	648	610	527	24	1020	650	611	527
10	27	1023	648	613	533	26	1019	650	614	533	25	1015	652	615	533	24	1011	654	616	533	23	1007	657	618	533
11	26	1012	654	619	538	25	1008	656	620	539	24	1003	658	621	539	23	959	701	622	539	22	954	703	624	539
12	25	1001	700	624	544	24	956	702	625	544	23	951	704	627	545	22	946	707	628	545	21	940	710	630	546
13	24	949	705	629	549	23	944	708	631	550	22	939	711	633	550	21	933	714	635	551	20	927	717	636	552
14	23	937	711	635	554	22	932	714	637	555	21	926	717	639	556	20	920	720	641	557	19	913	724	643	558
15	22	926	717	640	600	21	919	720	643	601	20	913	724	645	602	19	906	727	647	603	18	859	731	649	604
16	21	913	723	646	605	20	907	727	648	606	19	900	730	651	607	18	852	734	653	609	17	844	738	656	610
17	20	901	729	652	610	19	854	733	654	612	18	846	737	657	613	17	838	741	700	615	16	830	745	703	616
18	19	848	736	658	616	18	841	740	700	617	17	833	744	703	619	16	824	748	706	621	15	815	753	709	623
19	18	836	742	703	621	17	827	746	706	623	16	818	751	710	625	15	809	756	713	627	14	759	801	716	629
20	17	822	749	709	626	16	813	753	713	629	15	804	758	716	631	14	754	803	720	633	13	743	809	723	635
21	16	809	756	715	632	15	759	800	719	634	14	749	806	723	637	13	738	811	727	639	12	726	817	731	642
22	15	755	803	722	638	14	744	808	725	640	13	733	813	729	643	12	721	819	734	646	11	709	826	738	649
23	14	740	810	728	643	13	729	815	732	646	12	717	821	736	649	11	704	828	741	652	10	651	835	746	655
23.5	14	733	814	731	646	13	721	819	735	649	12	709	826	740	652	11	656	832	745	655	10	641	839	750	659

Table 2, Latitude and Declination SAME

DEC	LAT.58					LAT.59					LAT.60					LAT.61					LAT.62				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
0	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	32	1213	554	514	428	31	1213	554	513	425	30	1213	553	512	422	29	1214	553	510	418	28	1214	553	509	415
1	33	1225	547	508	421	32	1226	547	506	417	31	1227	546	505	414	30	1228	546	503	410	29	1229	545	501	406
2	34	1238	541	501	413	33	1240	540	459	410	32	1241	539	457	406	31	1243	539	455	402	30	1244	538	453	358
3	35	1251	534	455	406	34	1253	533	452	402	33	1255	532	450	358	32	1257	531	448	354	31	1300	530	445	349
4	36	1304	528	448	359	35	1307	527	445	354	34	1309	525	443	350	33	1312	524	440	345	32	1315	523	437	339
5	37	1317	521	441	351	36	1320	520	438	346	35	1323	518	435	341	34	1327	517	432	336	33	1330	515	429	330
6	38	1330	515	434	343	37	1334	513	431	338	36	1338	511	428	332	35	1342	509	424	326	34	1346	507	420	320
7	39	1344	508	427	335	38	1348	506	423	329	37	1352	504	420	323	36	1357	502	416	317	35	1402	459	412	310
8	40	1357	501	420	326	39	1402	459	416	320	38	1407	457	412	314	37	1412	454	408	307	36	1418	451	403	259
9	41	1411	455	412	318	40	1416	452	408	311	39	1421	449	404	304	38	1427	446	359	256	37	1434	443	354	247
10	42	1424	448	405	308	41	1430	445	400	301	40	1437	442	355	253	39	1443	438	350	244	38	1450	435	344	234
11	43	1439	441	357	259	42	1445	437	352	251	41	1452	434	347	242	40	1459	430	341	232	39	1507	426	335	221
12	44	1453	434	349	249	43	1500	430	343	240	42	1508	426	338	230	41	1516	422	331	219	40	1524	418	325	206
13	45	1507	426	340	238	44	1515	422	335	228	43	1524	418	328	217	42	1533	414	321	204	41	1542	409	314	149
14	46	1522	419	332	226	45	1531	415	326	215	44	1540	410	319	203	43	1550	405	311	148	42	1600	400	303	129
15	47	1538	411	323	214	46	1547	407	316	201	45	1557	402	308	146	44	1608	356	300	128	43	1619	350	251	103
16	48	1553	403	314	200	47	1604	358	306	145	46	1614	353	258	127	45	1626	347	249	102	44	1639	341	238	000
17	49	1610	355	304	144	48	1621	350	255	126	47	1632	344	246	101	46	1645	337	236	000	45	1659	330	224	///
18	50	1626	347	253	125	49	1638	341	244	101	48	1651	334	234	000	47	1705	327	222	///	46	1721	320	209	///
19	51	1644	338	242	100	50	1657	332	232	000	49	1711	325	221	///	48	1726	317	207	///	47	1743	309	152	///
20	52	1702	329	230	000	51	1716	322	219	///	50	1731	314	206	///	49	1748	306	150	///	48	1807	257	131	///
21	53	1721	320	217	///	52	1736	312	204	///	51	1753	304	149	///	50	1812	254	130	///	49	1832	244	105	///
22	54	1740	310	203	///	53	1757	301	148	///	52	1816	252	129	///	51	1837	242	104	///	50	1900	230	000	///
23	55	1801	259	147	///	54	1820	250	128	///	53	1841	240	103	///	52	1904	228	000	///	51	1930	215	///	///
23.5	56	1812	254	137	///	55	1832	244	116	///	54	1854	233	045	///	53	1918	221	///	///	52	1947	206	///	///

/// = Twilight lasts all night.

Latitude and Declination OPPOSITE

DEC	LAT.58					LAT.59					LAT.60					LAT.61					LAT.62				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
0	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	32	1213	554	514	428	31	1213	554	513	425	30	1213	553	512	422	29	1214	553	510	418	28	1214	553	509	415
1	31	1200	600	521	434	30	1200	600	520	432	29	1159	600	519	429	28	1159	600	518	426	27	1159	600	516	423
2	30	1147	607	527	441	29	1146	607	527	439	28	1146	607	526	437	27	1145	608	525	434	26	1144	608	524	431
3	29	1134	613	534	448	28	1133	614	533	446	27	1132	614	533	444	26	1130	615	532	442	25	1129	615	531	439
4	28	1121	619	540	455	27	1120	620	540	453	26	1118	621	540	451	25	1116	622	539	449	24	1114	623	539	447
5	27	1108	626	547	501	26	1106	627	547	500	25	1104	628	547	458	24	1101	629	547	457	23	1059	631	546	455
6	26	1055	632	553	508	25	1053	634	553	507	24	1050	635	554	505	23	1047	637	554	504	22	1043	638	554	503
7	25	1042	639	559	514	24	1039	641	600	513	23	1035	642	600	512	22	1032	644	601	511	21	1028	646	602	510
8	24	1029	645	606	521	23	1025	647	607	520	22	1021	649	607	519	21	1017	652	608	519	20	1012	654	609	518
9	23	1016	652	612	527	22	1011	654	613	527	21	1007	657	614	526	20	1002	659	615	526	19	956	702	617	525
10	22	1002	659	619	533	21	957	701	620	533	20	952	704	621	533	19	946	707	623	533	18	940	710	624	533
11	21	948	706	625	540	20	943	709	627	540	19	937	712	628	540	18	931	715	630	540	17	924	718	632	540
12	20	935	713	632	546	19	928	716	634	546	18	922	719	636	547	17	915	723	638	547	16	907	726	640	548
13	19	920	720	638	552	18	914	723	641	553	17	906	727	643	554	16	858	731	645	555	15	850	735	647	555
14	18	906	727	645	559	17	858	731	648	600	16	850	735	650	601	15	842	739	653	602	14	833	744	655	603
15	17	851	734	652	605	16	843	739	655	606	15	834	743	657	608	14	825	748	700	609	13	815	753	703	610
16	16	836	742	659	612	15	827	746	702	613	14	818	751	705	615	13	807	756	708	616	12	756	802	712	618
17	15	821	750	706	618	14	811	755	709	620	13	800	800	712	622	12	749	805	716	624	11	737	811	720	626
18	14	805	758	713	625	13	754	803	716	627	12	743	809	720	629	11	731	815	724	631	10	717	821	729	633
19	13	748	806	720	631	12	737	812	724	634	11	724	818	728	636	10	711	824	733	639	9	656	832	737	641
20	12	731	814	727	638	11	719	821	732	641	10	705	827	736	643	9	651	835	741	646	8	635	843	746	649
21	11	714	823	735	645	10	700	830	740	648	9	645	837	745	651	8	629	845	750	654	7	612	854	756	657
22	10	655	832	743	652	9	640	840	748	655	8	624	848	753	658	7	607	857	759	702	6	547	906	805	706
23	9	636	842	751	659	8	620	850	756	702	7	602	859	802	706	6	543	909	808	710	5	521	920	815	714
23.5	9	626	847	755	702	8	609	855	801	706	7	551	905	807	710	6	530	915	813	714	5	507	927	820	718

Table 2, Latitude and Declination SAME

DEC	LAT.63					LAT.64					LAT.65					LAT.66					LAT.67				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
0	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	27	1215	553	507	411	26	1215	552	505	407	25	1216	552	503	402	24	1216	552	500	357	23	1217	551	458	351
1	28	1230	545	459	402	27	1232	544	456	357	26	1233	544	454	352	25	1234	543	451	346	24	1236	542	448	340
2	29	1246	537	450	353	28	1248	536	448	348	27	1250	535	445	342	26	1252	534	442	335	25	1255	533	438	328
3	30	1302	529	442	343	29	1305	528	439	338	28	1308	526	436	331	27	1311	525	432	324	26	1314	523	428	316
4	31	1318	521	434	334	30	1321	519	430	327	29	1325	517	426	320	28	1329	516	422	312	27	1333	513	417	303
5	32	1334	513	425	323	31	1338	511	421	316	30	1343	509	417	308	29	1348	506	412	259	28	1353	504	407	249
6	33	1350	505	416	313	32	1355	502	412	305	31	1401	500	407	256	30	1406	457	401	246	29	1412	454	356	234
7	34	1407	457	407	302	33	1413	454	402	253	32	1419	451	357	243	31	1425	447	351	231	30	1433	444	344	217
8	35	1424	448	358	250	34	1430	445	352	240	33	1437	441	346	228	32	1445	438	340	215	31	1453	433	332	159
9	36	1441	440	348	237	35	1448	436	342	226	34	1456	432	335	212	33	1505	428	328	157	32	1514	423	320	137
10	37	1458	431	338	223	36	1506	427	331	210	35	1515	422	324	155	34	1525	418	316	135	33	1536	412	306	108
11	38	1516	422	328	208	37	1525	418	320	153	36	1535	413	312	133	35	1546	407	303	107	34	1558	401	252	000
12	39	1534	413	317	151	38	1544	408	309	132	37	1555	402	259	106	36	1607	356	249	000	35	1621	350	237	///
13	40	1553	404	306	130	39	1604	358	256	105	38	1616	352	246	000	37	1630	345	234	///	36	1645	338	220	///
14	41	1612	354	254	104	40	1624	348	243	000	39	1638	341	231	///	38	1653	333	218	///	37	1710	325	201	///
15	42	1632	344	241	000	41	1646	337	229	///	40	1701	330	215	///	39	1718	321	159	///	38	1736	312	139	///
16	43	1653	334	227	///	42	1708	326	213	///	41	1725	318	157	///	40	1744	308	137	///	39	1805	258	110	///
17	44	1714	323	211	///	43	1731	314	155	///	42	1750	305	136	///	41	1811	254	109	///	40	1835	242	000	///
18	45	1737	311	154	///	44	1756	302	134	///	43	1817	251	108	///	42	1841	240	000	///	41	1909	226	///	///
19	46	1802	259	133	///	45	1823	249	107	///	44	1846	237	000	///	43	1914	223	///	///	42	1946	207	///	///
20	47	1828	246	106	///	46	1851	234	000	///	45	1918	221	///	///	44	1951	205	///	///	43	2030	145	///	///
21	48	1856	232	000	///	47	1923	219	///	///	46	1955	203	///	///	45	2034	143	///	///	44	2126	117	///	///
22	49	1927	217	///	///	48	1958	201	///	///	47	2037	141	///	///	46	2129	116	///	///	45	2302	029	///	///
23	50	2002	159	///	///	49	2040	140	///	///	48	2131	114	///	///	47	2303	029	///	///	46	2400	+++	...	...
23.5	51	2021	149	///	///	50	2105	128	///	///	49	2207	056	///	///	48	2400	+++	...	...	47	2400	+++	...	...

/// = Twilight lasts all night.

* +++ = No rise or Set. Sun remains above the horizon.

Latitude and Declination OPPOSITE

DEC	LAT.63					LAT.64					LAT.65					LAT.66					LAT.67				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
0	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	27	1215	553	507	411	26	1215	552	505	407	25	1216	552	503	402	24	1216	552	500	357	23	1217	551	458	351
1	26	1159	601	515	420	25	1159	601	513	416	24	1159	601	512	412	23	1158	601	510	407	22	1158	601	508	402
2	25	1143	608	523	428	24	1142	609	522	425	23	1141	609	520	421	22	1140	610	519	417	21	1139	610	517	413
3	24	1128	616	531	437	23	1126	617	530	434	22	1124	618	529	431	21	1122	619	528	427	20	1120	620	527	423
4	23	1112	624	539	445	22	1109	625	538	442	21	1107	627	538	440	20	1104	628	537	437	19	1101	629	536	433
5	22	1056	632	546	453	21	1053	634	546	451	20	1050	635	546	449	19	1046	637	546	446	18	1042	639	546	443
6	21	1040	640	554	501	20	1036	642	554	459	19	1032	644	555	458	18	1028	646	555	455	17	1023	649	555	453
7	20	1024	648	602	509	19	1019	650	603	508	18	1014	653	603	506	17	1009	655	604	505	16	1003	658	605	503
8	19	1007	656	610	517	18	1002	659	611	516	17	956	702	612	515	16	950	705	613	514	15	943	708	614	512
9	18	951	705	618	525	17	945	708	619	524	16	938	711	620	524	15	931	715	622	523	14	923	718	623	522
10	17	934	713	626	533	16	927	717	627	532	15	919	720	629	532	14	911	724	631	532	13	903	729	633	531
11	16	917	722	634	540	15	909	726	636	541	14	900	730	638	541	13	851	734	640	541	12	841	739	643	541
12	15	859	730	642	548	14	850	735	644	549	13	841	740	647	549	12	831	745	650	550	11	820	750	653	550
13	14	841	739	650	556	13	832	744	653	557	12	821	749	656	558	11	810	755	659	559	10	757	802	702	559
14	13	823	749	658	604	12	812	754	702	605	11	800	800	705	606	10	748	806	709	608	9	734	813	713	609
15	12	804	758	707	612	11	752	804	710	613	10	739	810	714	615	9	725	818	718	617	8	709	825	723	618
16	11	744	808	715	620	10	731	814	719	622	9	717	822	724	624	8	701	829	729	626	7	644	838	734	628
17	10	724	818	724	628	9	710	825	729	630	8	654	833	734	632	7	636	842	739	635	6	616	852	745	638
18	9	703	829	733	636	8	647	837	738	639	7	629	845	744	641	6	610	855	749	644	5	547	906	756	648
19	8	641	840	742	644	7	623	849	748	647	6	603	858	754	650	5	541	909	800	654	4	516	922	808	658
20	7	617	851	752	652	6	558	901	758	656	5	535	912	805	700	4	510	925	812	703	3	441	939	820	708
21	6	552	904	802	701	5	530	915	808	705	4	505	927	816	709	3	436	942	824	713	2	401	959	833	718
22	5	525	917	812	710	4	501	930	819	714	3	432	944	827	718	2	357	1001	836	723	1	314	1023	846	729
23	4	456	932	823	718	3	428	946	831	723	2	354	1003	840	728	1	311	1025	850	734	0	211	1055	901	740
23.5	4	441	940	828	723	3	410	955	837	728	2	332	1014	846	733	1	243	1039	857	739	0	123	1119	908	745

Table 2, Latitude and Declination SAME

DEC	LAT.68					LAT.69					LAT.70					LAT.71					LAT.72				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
0	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	22	1218	551	455	345	21	1219	551	452	338	20	1219	550	449	330	19	1220	550	445	321	18	1222	549	441	311
1	23	1238	541	445	333	22	1239	540	441	325	21	1242	539	437	316	20	1244	538	433	306	19	1246	537	428	254
2	24	1258	531	434	320	23	1300	530	430	311	22	1304	528	425	301	21	1307	526	420	249	20	1311	524	414	235
3	25	1318	521	423	307	24	1322	519	418	257	23	1326	517	413	245	22	1331	515	407	231	21	1336	512	400	214
4	26	1338	511	412	253	25	1343	508	407	241	24	1349	506	400	227	23	1355	503	353	210	22	1402	459	345	149
5	27	1358	501	401	237	26	1405	458	354	224	25	1412	454	347	207	24	1419	450	339	146	23	1428	446	330	117
6	28	1419	450	349	220	27	1427	447	342	204	26	1435	443	334	143	25	1444	438	324	115	24	1454	433	314	000
7	29	1440	440	337	201	28	1449	435	329	141	27	1459	431	319	113	26	1509	425	309	000	25	1521	419	256	///
8	30	1502	429	324	139	29	1512	424	315	111	28	1523	418	304	000	27	1536	412	252	///	26	1550	405	237	///
9	31	1524	418	310	110	30	1536	412	300	000	29	1549	406	248	///	28	1603	359	233	///	27	1619	351	216	///
10	32	1547	406	256	000	31	1600	400	244	///	30	1615	353	229	///	29	1631	344	212	///	28	1650	335	150	///
11	33	1611	354	240	///	32	1626	347	226	///	31	1642	339	209	///	30	1701	330	148	///	29	1722	319	118	///
12	34	1636	342	223	///	33	1652	334	206	///	32	1711	325	145	///	31	1732	314	116	///	30	1757	302	000	///
13	35	1701	329	204	///	34	1720	320	143	///	33	1741	309	114	///	32	1806	257	000	///	31	1835	243	///	///
14	36	1729	316	141	///	35	1750	305	113	///	34	1814	253	000	///	33	1843	239	///	///	32	1917	221	///	///
15	37	1758	301	111	///	36	1822	249	000	///	35	1850	235	///	///	34	1924	218	///	///	33	2007	157	///	///
16	38	1829	246	000	///	37	1857	232	///	///	36	1930	215	///	///	35	2012	154	///	///	34	2109	125	///	///
17	39	1903	229	///	///	38	1936	212	///	///	37	2017	151	///	///	36	2113	123	///	///	35	2256	032	///	///
18	40	1941	209	///	///	39	2022	149	///	///	38	2117	122	///	///	37	2257	031	///	///	36	2400	+++	...	...
19	41	2026	147	///	///	40	2120	120	///	///	39	2258	031	///	///	38	2400	+++	...	...	37	2400	+++	...	...
20	42	2123	118	///	///	41	2300	030	///	///	40	2400	+++	...	...	39	2400	+++	...	...	38	2400	+++	...	...
21	43	2301	030	///	///	42	2400	+++	...	...	41	2400	+++	...	...	40	2400	+++	...	...	39	2400	+++	...	...
22	44	2400	+++	...	...	43	2400	+++	...	...	42	2400	+++	...	...	41	2400	+++	...	...	40	2400	+++	...	...
23	45	2400	+++	...	...	44	2400	+++	...	...	43	2400	+++	...	...	42	2400	+++	...	...	41	2400	+++	...	...
23.5	46	2400	+++	...	...	45	2400	+++	...	...	44	2400	+++	...	...	43	2400	+++	...	...	42	2400	+++	...	...

/// = Twilight lasts all night.

+++ = No rise or Set. Sun remains above the horizon.

Latitude and Declination OPPOSITE

DEC	LAT.68					LAT.69					LAT.70					LAT.71					LAT.72				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	22	1218	551	455	345	21	1219	551	452	338	20	1219	550	449	330	19	1220	550	445	321	18	1222	549	441	311
1	21	1158	601	505	357	20	1158	601	503	351	19	1158	601	500	344	18	1157	601	457	336	17	1157	602	454	327
2	20	1138	611	516	408	19	1137	612	514	403	18	1136	612	512	357	17	1134	613	509	350	16	1132	614	507	342
3	19	1118	621	526	419	18	1116	622	524	414	17	1113	623	523	409	16	1111	625	521	403	15	1108	626	519	357
4	18	1058	631	536	430	17	1055	633	535	426	16	1051	634	534	421	15	1047	636	533	416	14	1043	639	532	411
5	17	1038	641	545	440	16	1034	643	545	437	15	1029	646	545	433	14	1023	648	544	429	13	1017	651	544	424
6	16	1018	651	555	451	15	1012	654	556	448	14	1006	657	556	445	13	959	700	556	441	12	952	704	556	437
7	15	957	701	605	501	14	950	705	606	459	13	943	709	607	456	12	935	713	608	453	11	926	717	609	450
8	14	936	712	615	511	13	928	716	616	509	12	919	720	618	507	11	910	725	619	505	10	859	731	621	503
9	13	915	723	625	521	12	906	727	627	520	11	855	732	629	518	10	844	738	631	517	9	831	744	633	515
10	12	853	734	635	531	11	842	739	638	530	10	831	745	640	529	9	817	751	643	529	8	803	759	646	528
11	11	830	745	645	541	10	818	751	648	541	9	805	758	651	540	8	750	805	655	540	7	733	814	659	540
12	10	807	756	656	551	9	753	803	659	551	8	738	811	703	551	7	721	819	707	552	6	702	829	712	552
13	9	743	808	706	600	8	728	816	710	601	7	710	825	715	602	6	651	835	720	603	5	628	846	725	605
14	8	718	821	717	610	7	701	830	722	612	6	641	840	727	613	5	618	851	733	615	4	552	904	739	617
15	7	652	834	728	620	6	632	844	733	622	5	610	855	739	625	4	544	908	746	627	3	513	924	753	629
16	6	624	848	739	630	5	602	859	745	633	4	536	912	752	636	3	505	927	800	639	2	428	946	808	642
17	5	554	903	751	641	4	528	916	758	644	3	458	931	805	647	2	422	949	814	651	1	335	1012	824	655
18	4	522	919	803	651	3	452	934	811	655	2	416	952	819	659	1	330	1015	829	703	0	225	1048	840	708
18.5	4	505	928	809	656	3	432	944	817	700	2	352	1004	827	705	1	259	1030	837	709	0	131	1114	849	715
19	3	446	937	815	702	2	411	955	824	706	1	326	1017	834	711	0	221	1049	845	716	-1	000	---	858	721
19.5	3	427	947	822	707	2	347	1006	831	712	1	255	1032	842	717	0	129	1115	854	722	-1	000	---	908	728
20	2	406	957	829	712	1	321	1019	839	717	0	218	1051	850	723	-1	000	---	903	729	-2	000	---	918	735
20.5	2	343	1008	835	718	1	252	1034	846	723	0	127	1116	858	729	-1	000	---	912	735	-2	000	---	929	742
21	1	318	1021	843	723	0	216	1052	854	729	-1	000	---	907	735	-2	000	---	922	742	-3	000	---	940	750
21.5	1	248	1036	850	729	0	126	1117	902	735	-1	000	---	916	742	-2	000	---	932	749	-3	000	---	952	757
22	0	213	1053	857	735	-1	000	---	910	741	-2	000	---	925	748	-3	000	---	943	756	-4	000	---	1006	805
22.5	0	124	1118	905	740	-1	000	---	919	747	-2	000	---	935	755	-3	000	---	955	803	-4	000	---	1021	813
23	-1	000	---	913	746	-2	000	---	928	754	-3	000	---	946	802	-4	000	---	1009	810	-5	000	---	1039	821
23.5	-1	000	---	922	752	-2	000	---	938	800	-3	000	---	958	808	-4	000	---	1024	818	-5	000	---	1103	829

Table 2, Latitude and Declination SAME

DEC	LAT.73					LAT.74					LAT.75					LAT.76					LAT.77				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
0	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	17	1223	549	436	259	16	1224	548	431	244	15	1226	547	425	226	14	1228	546	418	203	13	1230	545	409	130
1	18	1249	535	422	239	17	1252	534	416	222	16	1256	532	408	159	15	1300	530	359	127	14	1305	528	349	000
2	19	1316	522	407	217	18	1320	520	400	155	17	1326	517	351	124	16	1332	514	340	000	15	1340	510	328	///
3	20	1342	509	352	152	19	1349	505	343	121	18	1357	502	333	000	17	1406	457	320	///	16	1416	452	305	///
4	21	1409	455	336	119	20	1418	451	326	000	19	1428	446	313	///	18	1439	440	258	///	17	1453	434	239	///
5	22	1437	441	319	000	21	1448	436	307	///	20	1500	430	252	///	19	1514	423	233	///	18	1531	415	209	///
6	23	1506	427	301	///	22	1518	421	246	///	21	1533	413	228	///	20	1551	405	205	///	19	1611	355	131	///
7	24	1535	413	242	///	23	1550	405	224	///	22	1608	356	200	///	21	1629	346	128	///	20	1653	333	000	///
8	25	1605	357	219	///	24	1623	348	157	///	23	1644	338	125	///	22	1709	325	000	///	21	1739	310	///	///
9	26	1637	341	153	///	25	1658	331	122	///	24	1723	318	000	///	23	1753	304	///	///	22	1830	245	///	///
10	27	1711	325	120	///	26	1736	312	000	///	25	1805	257	///	///	24	1842	239	///	///	23	1928	216	///	///
11	28	1747	307	000	///	27	1816	252	///	///	26	1852	234	///	///	25	1938	211	///	///	24	2042	139	///	///
12	29	1826	247	///	///	28	1901	229	///	///	27	1946	207	///	///	26	2048	136	///	///	25	2245	037	///	///
13	30	1910	225	///	///	29	1954	203	///	///	28	2055	133	///	///	27	2248	036	///	///	26	2400	+++	...	...
14	31	2001	200	///	///	30	2100	130	///	///	29	2250	035	///	///	28	2400	+++	...	...	27	2400	+++	...	...
15	32	2105	128	///	///	31	2252	034	///	///	30	2400	+++	...	...	29	2400	+++	...	...	28	2400	+++	...	...
16	33	2254	033	///	///	32	2400	+++	...	...	31	2400	+++	...	...	30	2400	+++	...	...	29	2400	+++	...	...
17	34	2400	+++	...	...	33	2400	+++	...	...	32	2400	+++	...	...	31	2400	+++	...	...	30	2400	+++	...	...
18	35	2400	+++	...	...	34	2400	+++	...	...	33	2400	+++	...	...	32	2400	+++	...	...	31	2400	+++	...	...
19	36	2400	+++	...	...	35	2400	+++	...	...	34	2400	+++	...	...	33	2400	+++	...	...	32	2400	+++	...	...
20	37	2400	+++	...	...	36	2400	+++	...	...	35	2400	+++	...	...	34	2400	+++	...	...	33	2400	+++	...	...
21	38	2400	+++	...	...	37	2400	+++	...	...	36	2400	+++	...	...	35	2400	+++	...	...	34	2400	+++	...	...
22	39	2400	+++	...	...	38	2400	+++	...	...	37	2400	+++	...	...	36	2400	+++	...	...	35	2400	+++	...	...
23	40	2400	+++	...	...	39	2400	+++	...	...	38	2400	+++	...	...	37	2400	+++	...	...	36	2400	+++	...	...
23.5	41	2400	+++	...	...	40	2400	+++	...	...	39	2400	+++	...	...	38	2400	+++	...	...	37	2400	+++	...	...

/// = Twilight lasts all night.

+++ = No rise or Set. Sun remains above the horizon.

Latitude and Declination OPPOSITE

DEC	LAT.73					LAT.74					LAT.75					LAT.76					LAT.77				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
0	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	17	1223	549	436	259	16	1224	548	431	244	15	1226	547	425	226	14	1228	546	418	203	13	1230	545	409	130
1	16	1157	602	450	317	15	1156	602	446	304	14	1156	602	441	250	13	1155	602	435	231	12	1155	603	428	208
2	15	1130	615	504	333	14	1128	616	500	323	13	1126	617	456	311	12	1123	618	452	256	11	1120	620	447	237
3	14	1104	628	517	349	13	1100	630	515	340	12	1056	632	512	330	11	1051	635	509	318	10	1045	637	505	303
4	13	1038	641	530	404	12	1032	644	529	357	11	1026	647	527	348	10	1018	651	525	338	9	1010	655	522	326
5	12	1011	655	543	419	11	1003	658	543	412	10	955	703	542	405	9	945	708	541	357	8	934	713	540	347
6	11	943	708	556	433	10	934	713	557	428	9	923	718	557	422	8	911	725	557	415	7	856	732	557	407
7	10	915	722	609	447	9	904	728	611	442	8	851	735	612	438	7	835	742	613	432	6	817	751	615	426
8	9	847	737	623	500	8	833	744	625	457	7	817	752	627	453	6	758	801	629	449	5	737	812	632	444
9	8	817	752	636	513	7	801	800	639	511	6	742	809	642	509	5	720	820	646	506	4	653	833	650	502
10	7	746	807	649	527	6	727	817	653	525	5	704	828	657	524	4	638	841	702	522	3	606	857	708	520
11	6	714	823	703	540	5	651	834	708	539	4	625	848	713	539	3	553	904	719	538	2	513	924	727	537
12	5	639	840	717	553	4	613	854	723	553	3	541	910	729	554	2	502	929	737	554	1	410	955	746	554
13	4	602	859	731	606	3	531	915	738	607	2	452	934	746	609	1	402	959	755	610	0	248	1036	806	612
13.5	4	542	909	739	612	3	508	926	746	614	2	424	948	755	616	1	326	1017	805	618	0	146	1107	817	621
14	3	521	919	746	619	2	443	938	754	621	1	354	1003	804	624	0	242	1039	815	626	-1	000	---	828	629
14.5	3	459	930	754	626	2	417	952	803	628	1	319	1020	813	631	0	142	1109	825	634	-1	000	---	839	638
15	2	435	942	802	632	1	347	1006	811	635	0	237	1041	822	639	-1	000	---	835	643	-2	000	---	851	647
15.5	2	410	955	810	639	1	313	1023	820	643	0	139	1110	832	646	-1	000	---	846	651	-2	000	---	904	656
16	1	341	1010	818	646	0	233	1044	829	650	-1	000	---	842	654	-2	000	---	858	659	-3	000	---	917	705
16.5	1	308	1026	826	653	0	136	1112	838	657	-1	000	---	853	702	-2	000	---	910	708	-3	000	---	932	714
17	0	228	1046	835	659	-1	000	---	848	704	-2	000	---	904	710	-3	000	---	923	716	-4	000	---	948	724
17.5	0	134	1113	844	706	-1	000	---	858	712	-2	000	---	915	718	-3	000	---	937	725	-4	000	---	1006	733
18	-1	000	---	854	713	-2	000	---	909	720	-3	000	---	928	726	-4	000	---	952	734	-5	000	---	1027	743
19	-2	000	---	914	728	-3	000	---	932	735	-4	000	---	956	743	-5	000	---	1030	753	-6	000	---	1200	804
20	-3	000	---	936	743	-4	000	---	1000	751	-5	000	---	1033	801	-6	000	---	1200	812	-7	000	---	...	825
21	-4	000	---	1003	758	-5	000	---	1035	808	-6	000	---	1200	820	-7	000	---	...	833	-8	000	---	...	849
22	-5	000	---	1038	815	-6	000	---	1200	826	-7	000	---	...	840	-8	000	---	...	856	-9	000	---	...	915
23	-6	000	---	1200	832	-7	000	---	...	845	-8	000	---	...	901	-9	000	---	...	921	-10	000	---	...	946
23.5	-6	000	---	...	841	-7	000	---	...	856	-8	000	---	...	913	-9	000	---	...	935	-10	000	---	...	1004

--- = No Rise or Set. Sun remains below the horizon.

Table 2, Latitude and Declination SAME

DEC	LAT.78					LAT.79					LAT.80					LAT.81					LAT.82				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
0	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	12	1232	544	359	000	11	1235	543	347	///	10	1238	541	332	///	9	1243	539	312	///	8	1248	536	245	///
1	13	1310	525	337	///	12	1316	522	322	///	11	1324	518	302	///	10	1334	513	236	///	9	1346	507	156	///
2	14	1348	506	313	///	13	1359	501	253	///	12	1411	455	227	///	11	1426	447	149	///	10	1445	437	000	///
3	15	1428	446	246	///	14	1442	439	220	///	13	1459	430	143	///	12	1521	420	000	///	11	1548	406	///	///
4	16	1508	426	214	///	15	1527	417	139	///	14	1550	405	000	///	13	1619	351	///	///	12	1656	332	///	///
5	17	1550	405	134	///	16	1614	353	000	///	15	1644	338	///	///	14	1722	319	///	///	13	1813	253	///	///
6	18	1635	342	000	///	17	1705	328	///	///	16	1743	309	///	///	15	1834	243	///	///	14	1948	206	///	///
7	19	1723	318	///	///	18	1801	300	///	///	17	1851	235	///	///	16	2003	159	///	///	15	2226	047	///	///
8	20	1816	252	///	///	19	1905	227	///	///	18	2015	153	///	///	17	2231	044	///	///	16	2400	+++	...	...
9	21	1917	221	///	///	20	2025	148	///	///	19	2235	042	///	///	18	2400	+++	...	...	17	2400	+++	...	...
10	22	2034	143	///	///	21	2239	040	///	///	20	2400	+++	...	...	19	2400	+++	...	...	18	2400	+++	...	...
11	23	2243	039	///	///	22	2400	+++	...	...	21	2400	+++	...	...	20	2400	+++	...	...	19	2400	+++	...	...
12	24	2400	+++	...	...	23	2400	+++	...	...	22	2400	+++	...	...	21	2400	+++	...	...	20	2400	+++	...	...
13	25	2400	+++	...	...	24	2400	+++	...	...	23	2400	+++	...	...	22	2400	+++	...	...	21	2400	+++	...	...
14	26	2400	+++	...	...	25	2400	+++	...	...	24	2400	+++	...	...	23	2400	+++	...	...	22	2400	+++	...	...
15	27	2400	+++	...	...	26	2400	+++	...	...	25	2400	+++	...	...	24	2400	+++	...	...	23	2400	+++	...	...
16	28	2400	+++	...	...	27	2400	+++	...	...	26	2400	+++	...	...	25	2400	+++	...	...	24	2400	+++	...	...
17	29	2400	+++	...	...	28	2400	+++	...	...	27	2400	+++	...	...	26	2400	+++	...	...	25	2400	+++	...	...
18	30	2400	+++	...	...	29	2400	+++	...	...	28	2400	+++	...	...	27	2400	+++	...	...	26	2400	+++	...	...
19	31	2400	+++	...	...	30	2400	+++	...	...	29	2400	+++	...	...	28	2400	+++	...	...	27	2400	+++	...	...
20	32	2400	+++	...	...	31	2400	+++	...	...	30	2400	+++	...	...	29	2400	+++	...	...	28	2400	+++	...	...
21	33	2400	+++	...	...	32	2400	+++	...	...	31	2400	+++	...	...	30	2400	+++	...	...	29	2400	+++	...	...
22	34	2400	+++	...	...	33	2400	+++	...	...	32	2400	+++	...	...	31	2400	+++	...	...	30	2400	+++	...	...
23	35	2400	+++	...	...	34	2400	+++	...	...	33	2400	+++	...	...	32	2400	+++	...	...	31	2400	+++	...	...
23.5	36	2400	+++	...	...	35	2400	+++	...	...	34	2400	+++	...	...	33	2400	+++	...	...	32	2400	+++	...	...

/// = Twilight lasts all night.

+++ = No rise or Set. Sun remains above the horizon.

Latitude and Declination OPPOSITE

DEC	LAT.78					LAT.79					LAT.80					LAT.81					LAT.82				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
0	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	12	1232	544	359	000	11	1235	543	347	///	10	1238	541	332	///	9	1243	539	312	///	8	1248	536	245	///
1	11	1154	603	420	133	10	1154	603	411	000	9	1153	603	359	///	8	1152	604	344	///	7	1151	605	325	///
2	10	1117	622	441	213	9	1113	624	434	138	8	1108	626	425	000	7	1101	629	414	///	6	1054	633	359	///
3	9	1039	641	500	244	8	1031	645	455	219	7	1021	649	449	142	6	1010	655	441	000	5	956	702	431	///
4	8	1000	700	520	311	7	948	706	516	252	6	934	713	512	226	5	917	722	507	148	4	855	733	501	000
5	7	920	720	539	335	6	905	728	537	320	5	845	737	535	300	4	821	749	533	234	3	751	805	530	155
6	6	839	740	557	357	5	819	751	558	345	4	754	803	558	330	3	722	819	558	311	2	640	840	558	244
7	5	756	802	616	418	4	730	815	618	409	3	658	831	621	357	2	616	852	623	343	1	518	921	627	323
8	4	710	825	635	438	3	638	841	639	431	2	557	902	644	423	1	500	930	649	412	0	332	1014	656	358
8.5	4	646	837	645	448	3	610	855	650	442	2	522	919	655	435	1	415	953	702	426	0	214	1053	711	414
9	3	621	850	655	458	2	540	910	700	453	1	445	938	707	447	0	320	1020	715	439	-1	000	---	726	429
9.5	3	554	903	704	508	2	507	926	711	504	1	402	959	719	459	0	206	1057	729	452	-1	000	---	742	444
10	2	525	917	714	517	1	431	944	722	514	0	310	1025	732	510	-1	000	---	743	505	-2	000	---	758	459
10.5	2	454	933	725	527	1	351	1005	733	524	0	200	1100	744	522	-1	000	---	758	518	-2	000	---	815	514
11	1	420	950	735	536	0	302	1029	745	535	-1	000	---	757	533	-2	000	---	813	531	-3	000	---	833	528
11.5	1	341	1009	745	545	0	155	1103	757	545	-1	000	---	811	544	-2	000	---	828	544	-3	000	---	852	542
12	0	254	1033	756	555	-1	000	---	809	555	-2	000	---	825	556	-3	000	---	845	556	-4	000	---	912	557
12.5	0	150	1105	807	604	-1	000	---	822	606	-2	000	---	839	607	-3	000	---	903	609	-4	000	---	936	611
13	-1	000	---	819	614	-2	000	---	835	616	-3	000	---	855	618	-4	000	---	922	621	-5	000	---	1003	625
14	-2	000	---	844	633	-3	000	---	904	637	-4	000	---	930	641	-5	000	---	1009	647	-6	000	---	1200	654
15	-3	000	---	911	652	-4	000	---	937	658	-5	000	---	1015	705	-6	000	---	1200	714	-7	000	---	...	724
16	-4	000	---	943	712	-5	000	---	1019	720	-6	000	---	1200	729	-7	000	---	...	741	-8	000	---	...	756
17	-5	000	---	1023	732	-6	000	---	1200	743	-7	000	---	...	755	-8	000	---	...	811	-9	000	---	...	831
18	-6	000	---	1200	754	-7	000	---	...	807	-8	000	---	...	823	-9	000	---	...	843	-10	000	---	...	911
19	-7	000	---	...	817	-8	000	---	...	833	-9	000	---	...	853	-10	000	---	...	921	-11	000	---	...	1002
20	-8	000	---	...	842	-9	000	---	...	902	-10	000	---	...	929	-11	000	---	...	1008	-12	000	---	...	1200
21	-9	000	---	...	909	-10	000	---	...	935	-11	000	---	...	1014	-12	000	---	...	1200	-13	000	---	...	...
22	-10	000	---	...	941	-11	000	---	...	1018	-12	000	---	...	1200	-13	000	---	...	...	-14	000	---	...	...
23	-11	000	---	...	1022	-12	000	---	...	1200	-13	000	---	...	...	-14	000	---	...	...	-15	000	---	...	...
23.5	-11	000	---	...	1051	-12	000	---	...	...	-13	000	---	...	...	-14	000	---	...	...	-15	000	---	...	...

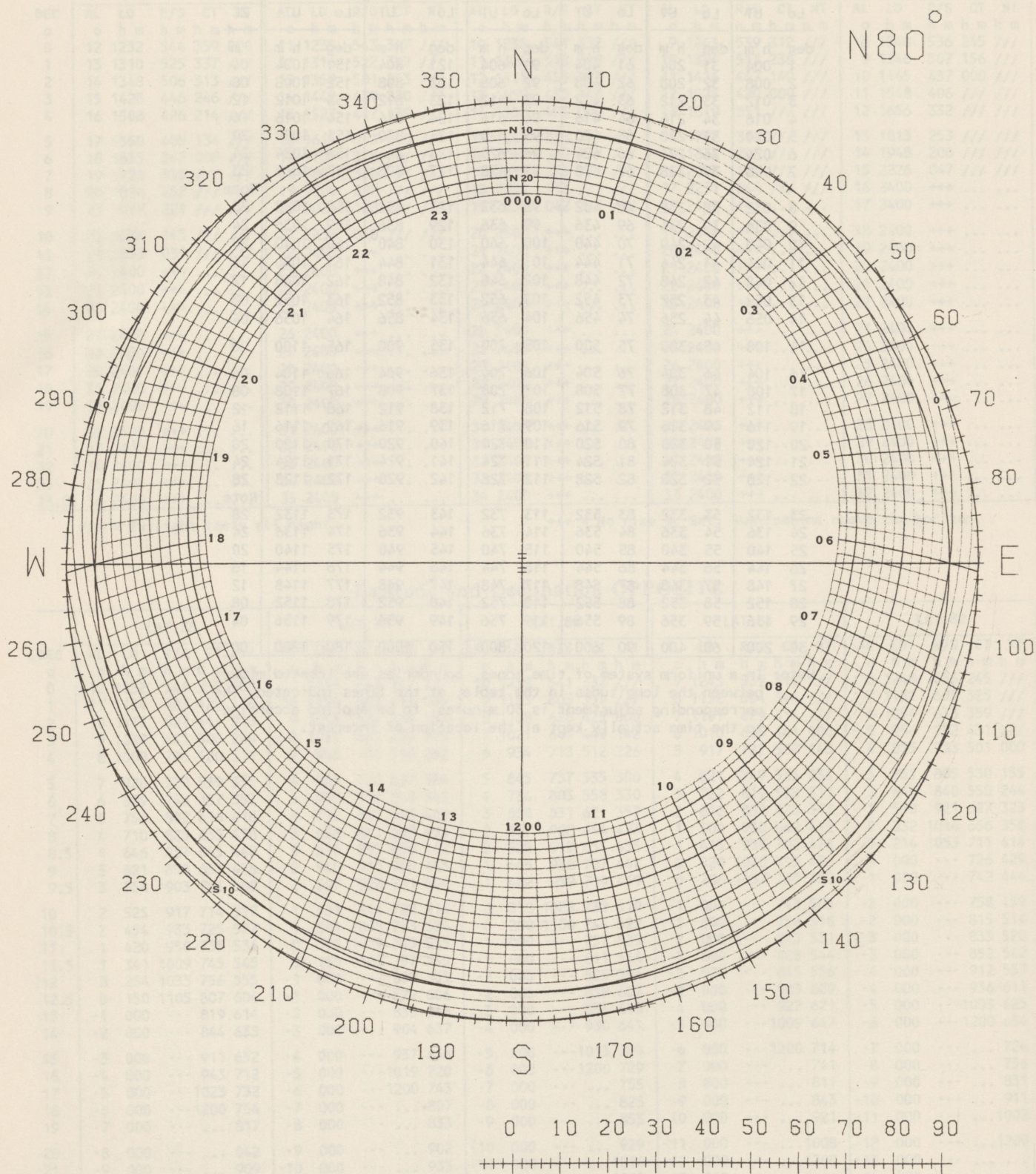
--- = No Rise or Set. Sun remains below the horizon.

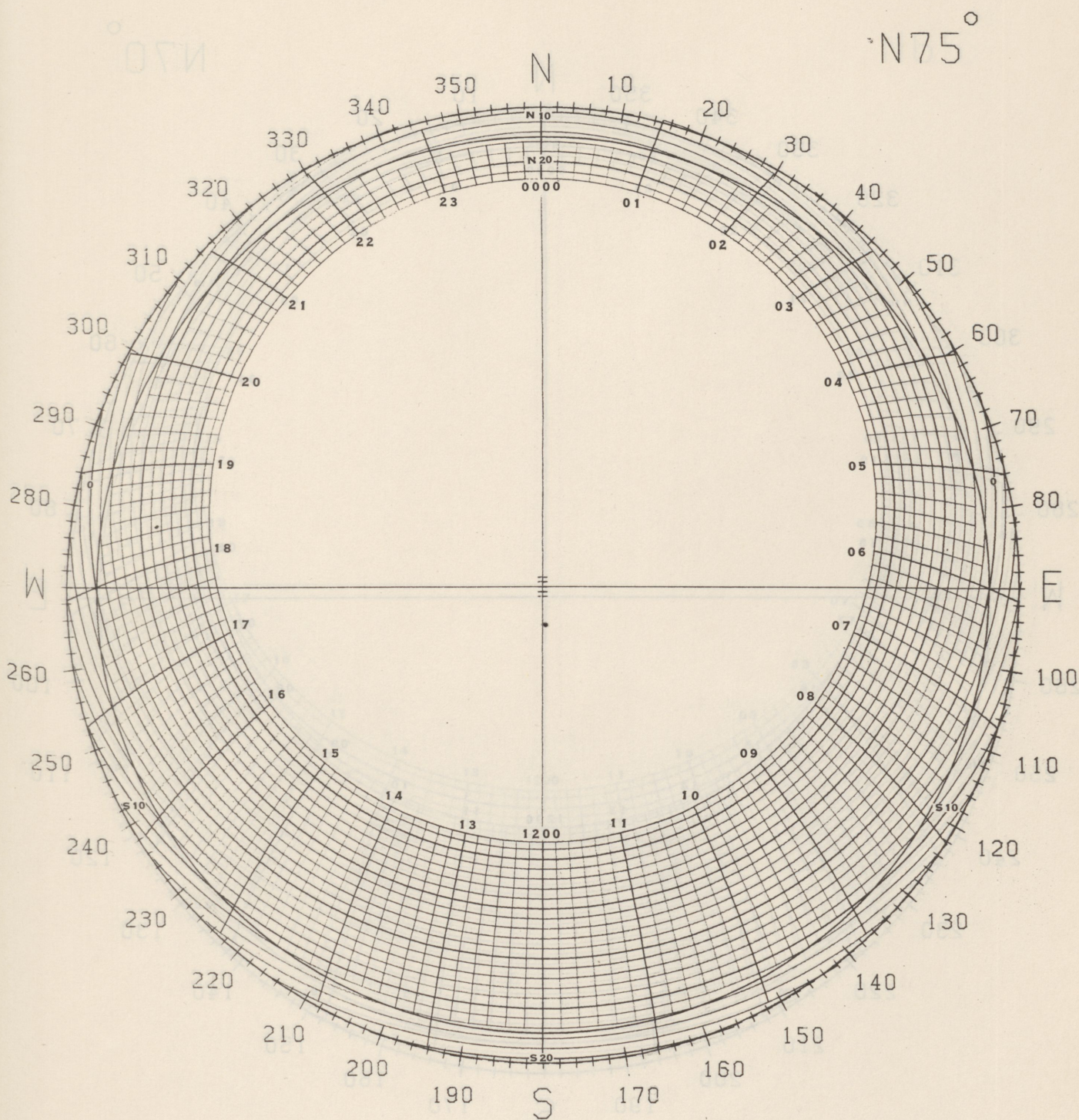
/// = Twilight lasts all night.

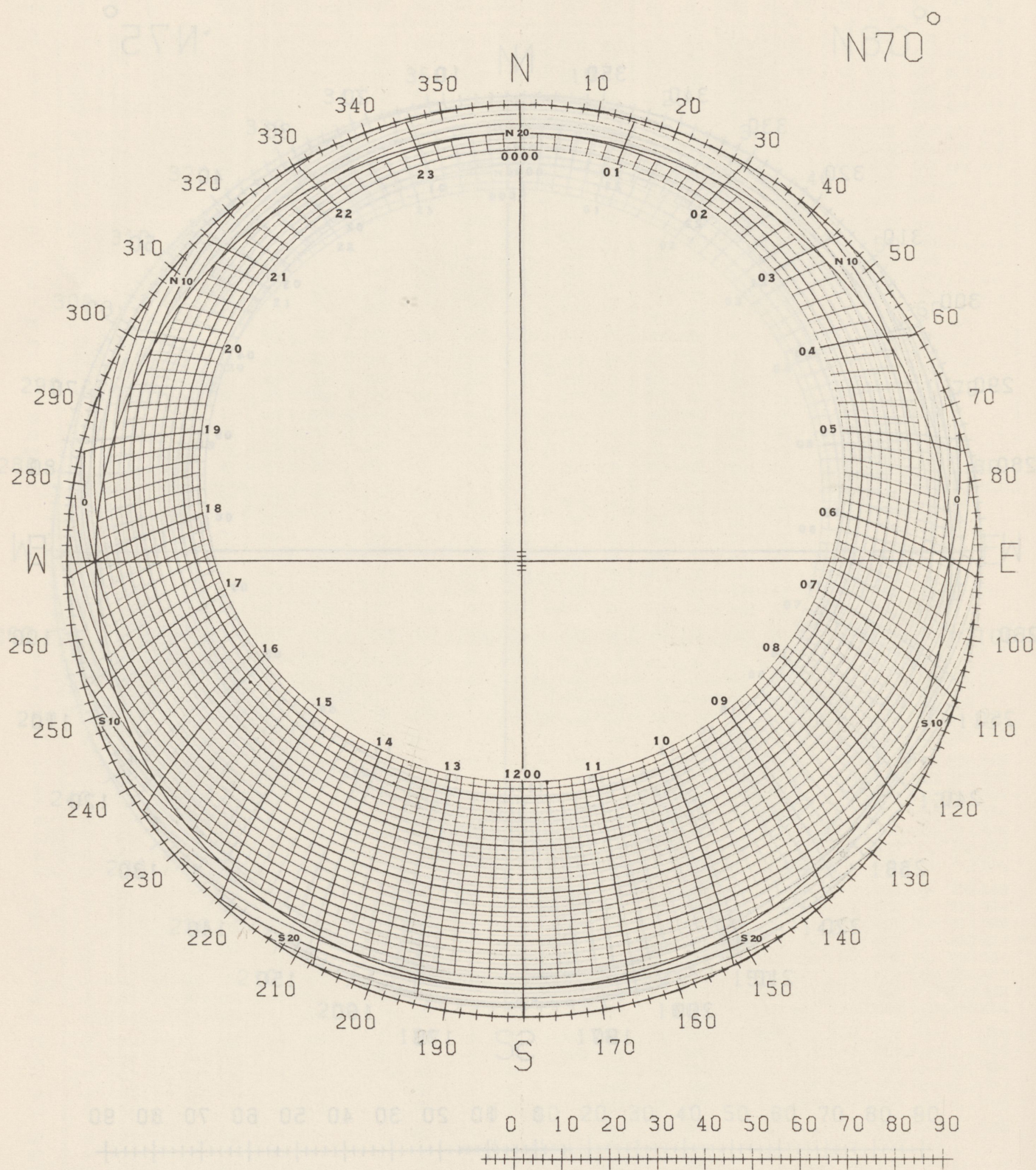
Table 3 -- Longitude, Time Adjustments

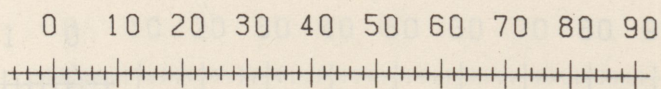
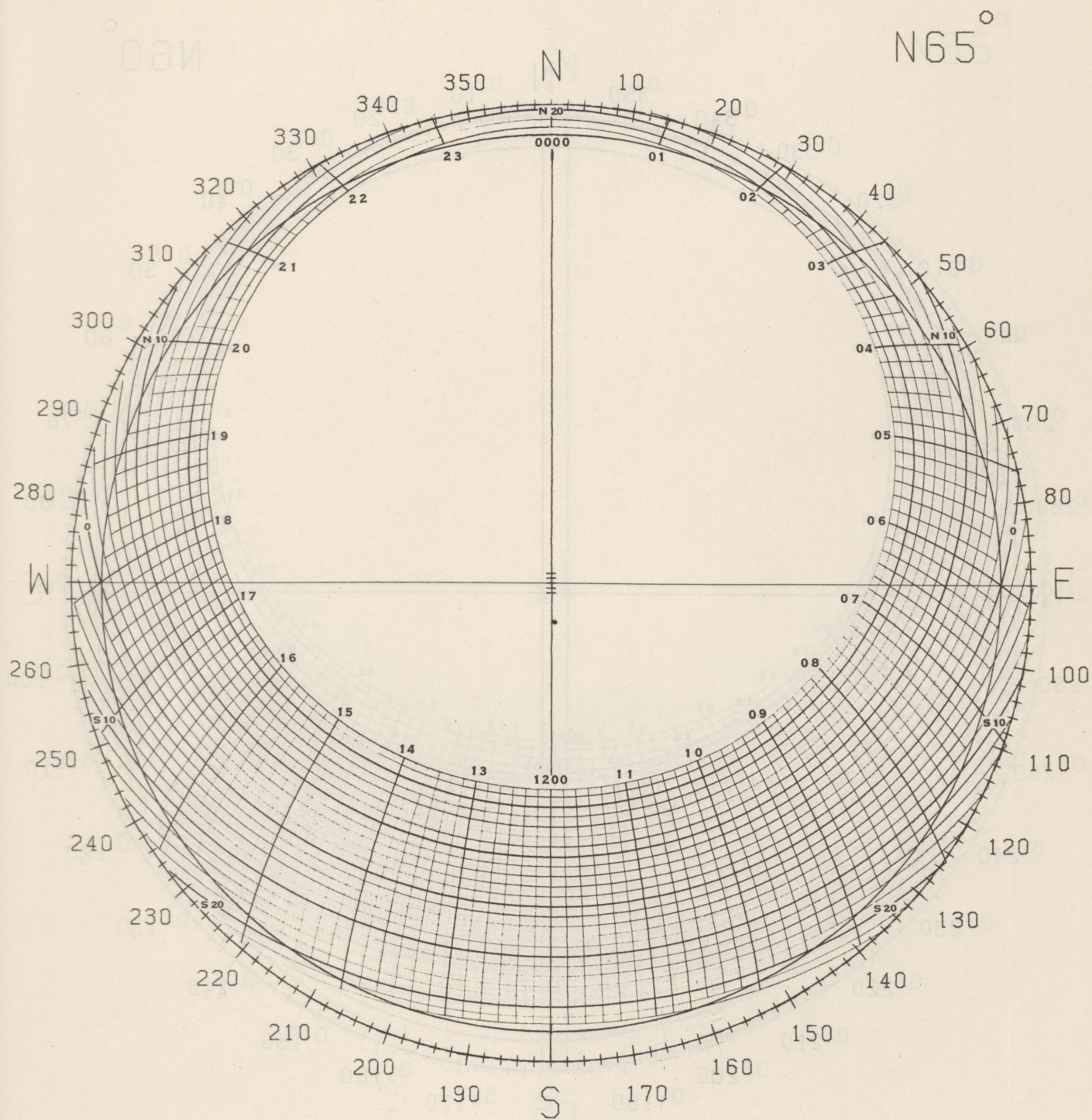
Lo	UT	Lo	UT	Lo	UT	Lo	UT	Lo	UT	Lo	UT	ZC
deg	h m	deg	h m	deg	h m	deg	h m	deg	h m	deg	h m	m
1	004	31	204	61	404	91	604	121	804	151	1004	04
2	008	32	208	62	408	92	608	122	808	152	1008	08
3	012	33	212	63	412	93	612	123	812	153	1012	12
4	016	34	216	64	416	94	616	124	816	154	1016	16
5	020	35	220	65	420	95	620	125	820	155	1020	20
6	024	36	224	66	424	96	624	126	824	156	1024	24
7	028	37	228	67	428	97	628	127	828	157	1028	28
												Note
8	032	38	232	68	432	98	632	128	832	158	1032	28
9	036	39	236	69	436	99	636	129	836	159	1036	24
10	040	40	240	70	440	100	640	130	840	160	1040	20
11	044	41	244	71	444	101	644	131	844	161	1044	16
12	048	42	248	72	448	102	648	132	848	162	1048	12
13	052	43	252	73	452	103	652	133	852	163	1052	08
14	056	44	256	74	456	104	656	134	856	164	1056	04
15	100	45	300	75	500	105	700	135	900	165	1100	00
16	104	46	304	76	504	106	704	136	904	166	1104	04
17	108	47	308	77	508	107	708	137	908	167	1108	08
18	112	48	312	78	512	108	712	138	912	168	1112	12
19	116	49	316	79	516	109	716	139	916	169	1116	16
20	120	50	320	80	520	110	720	140	920	170	1120	20
21	124	51	324	81	524	111	724	141	924	171	1124	24
22	128	52	328	82	528	112	728	142	928	172	1128	28
												Note
23	132	53	332	83	532	113	732	143	932	173	1132	28
24	136	54	336	84	536	114	736	144	936	174	1136	24
25	140	55	340	85	540	115	740	145	940	175	1140	20
26	144	56	344	86	544	116	744	146	944	176	1144	16
27	148	57	348	87	548	117	748	147	948	177	1148	12
28	152	58	352	88	552	118	752	148	952	178	1152	08
29	156	59	356	89	556	119	756	149	956	179	1156	04
30	200	60	400	90	600	120	800	150	1000	180	1200	00

Note: In a uniform system of time zones, boundaries are located midway between the longitudes in the table, at the lines indicated. The corresponding adjustment is 30 minutes, to be applied according to the time actually kept at the location of interest.

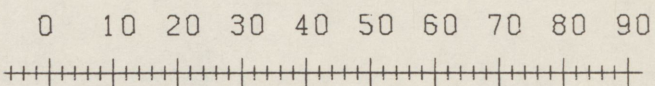
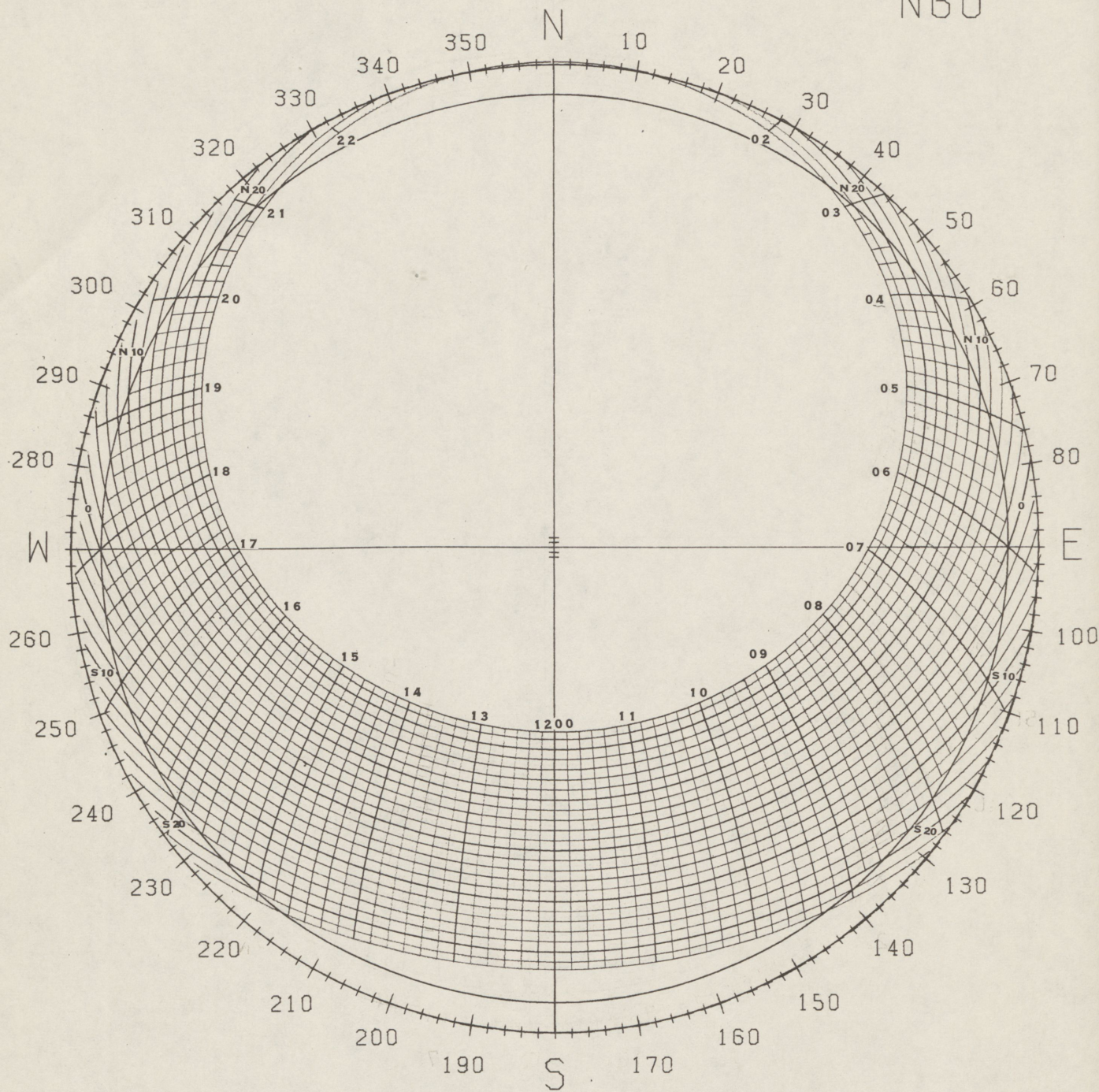


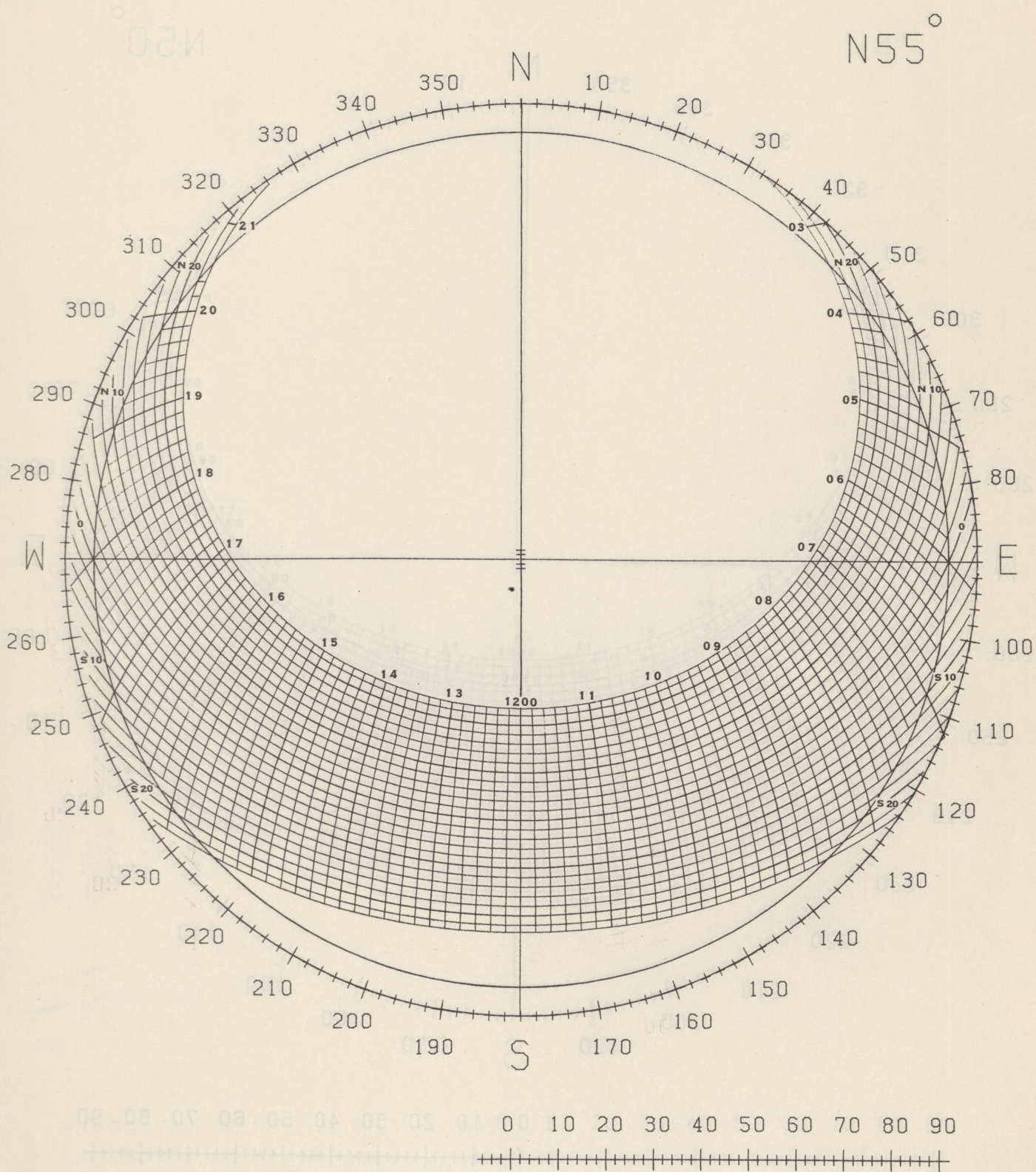


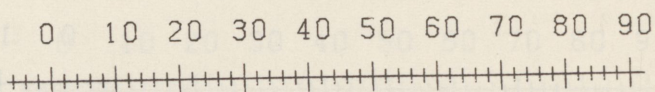
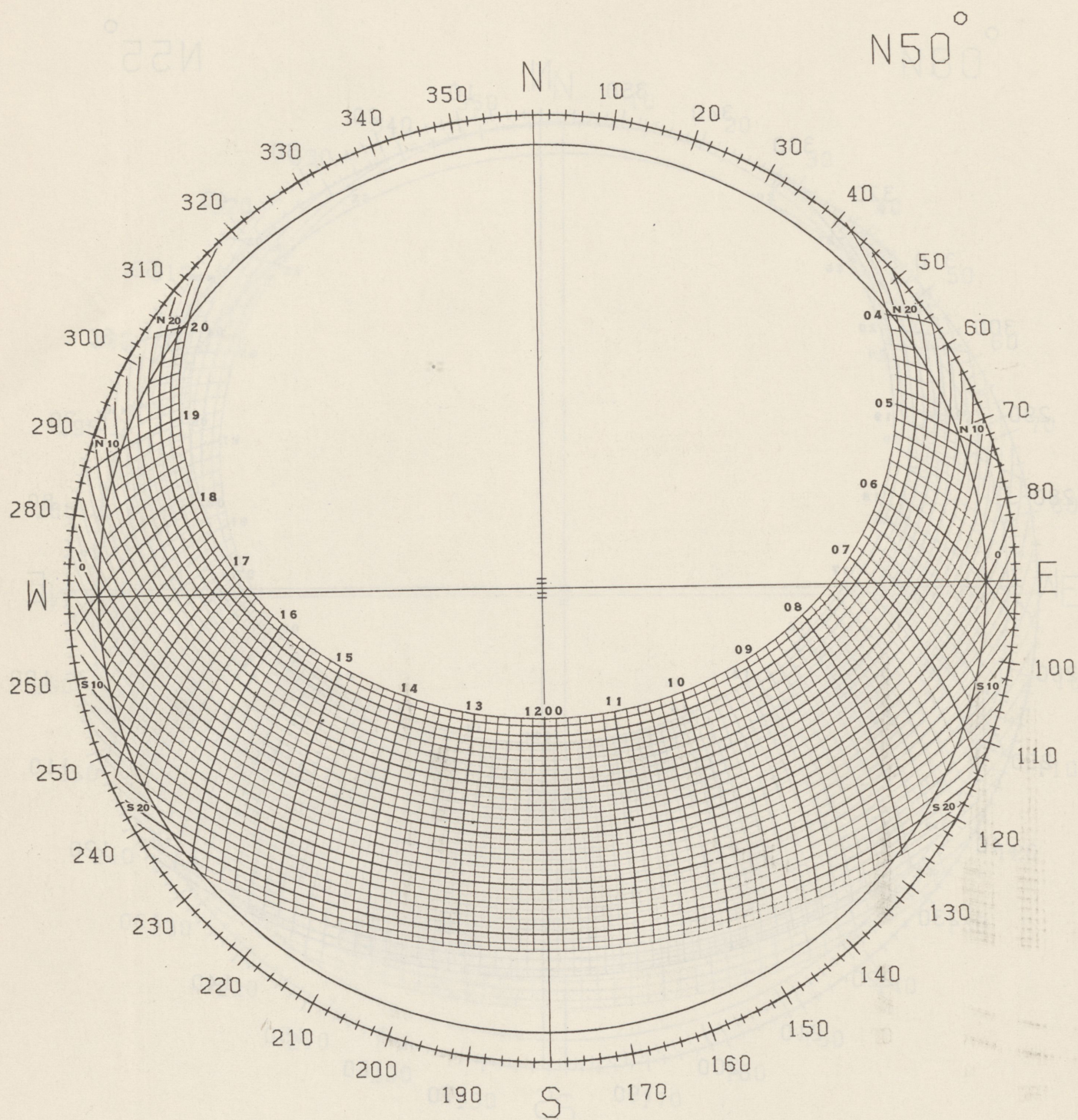


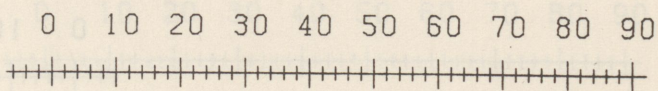
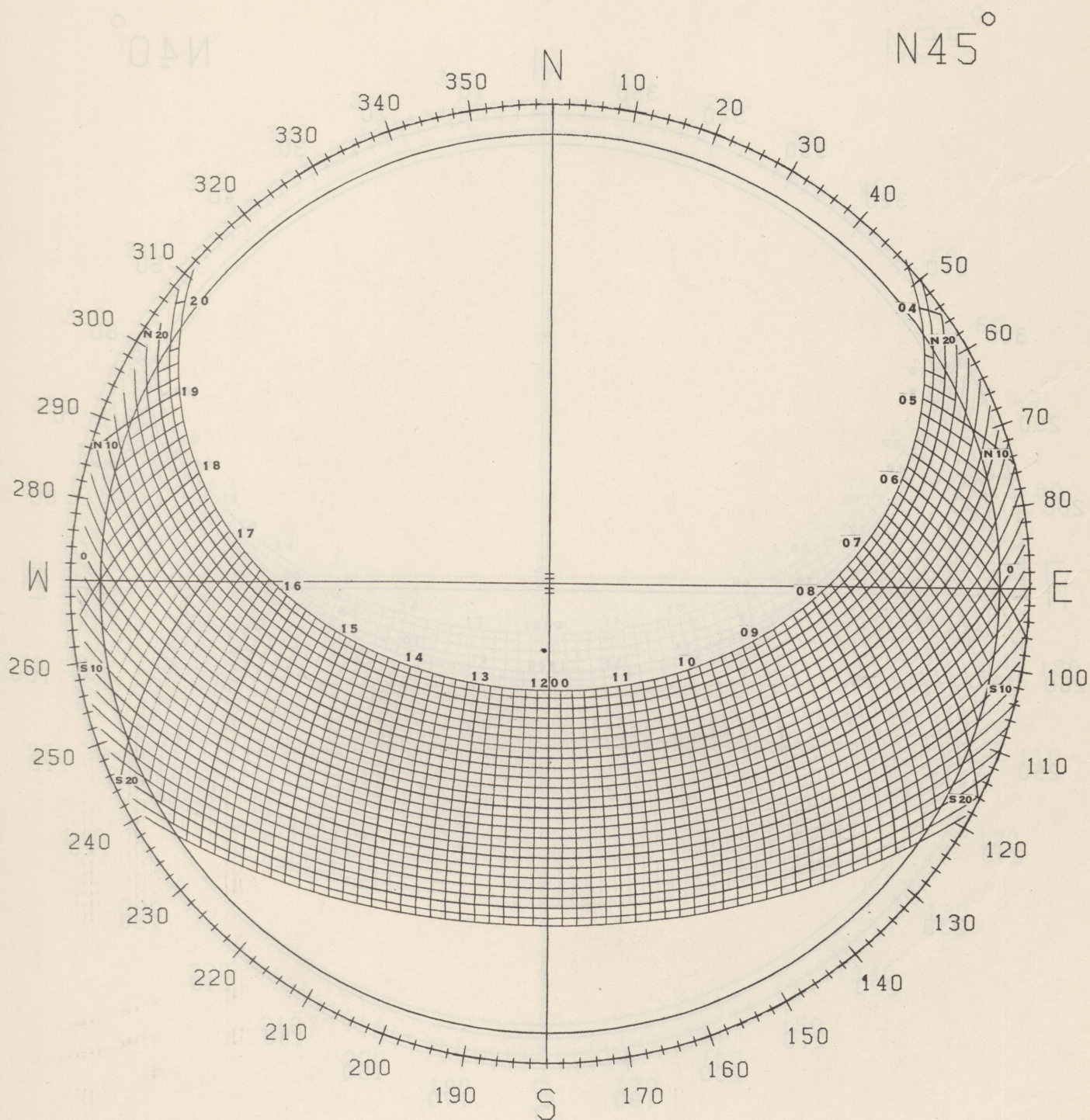


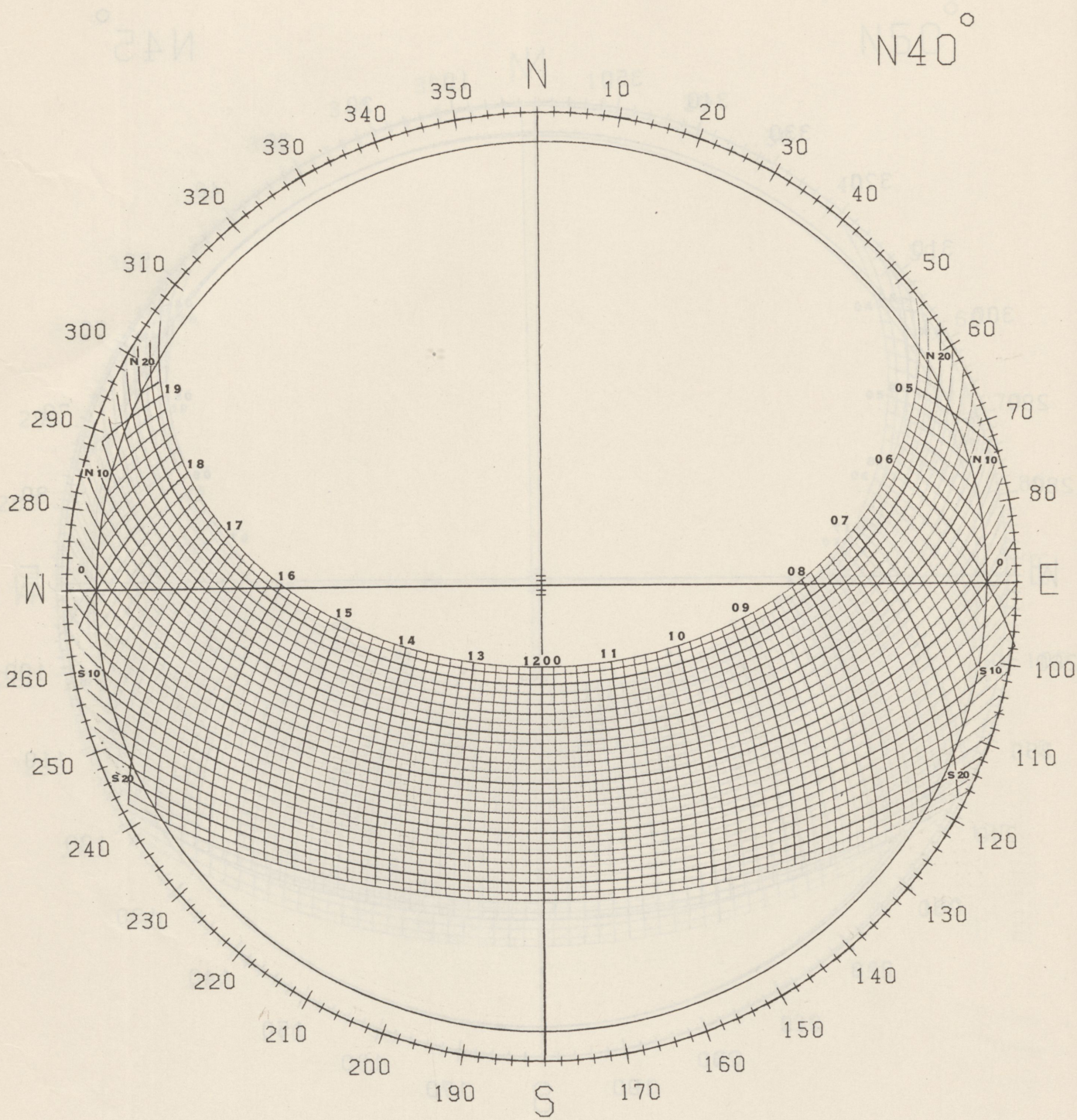
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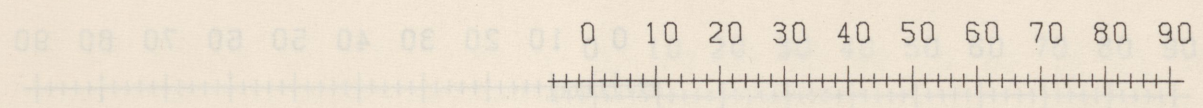
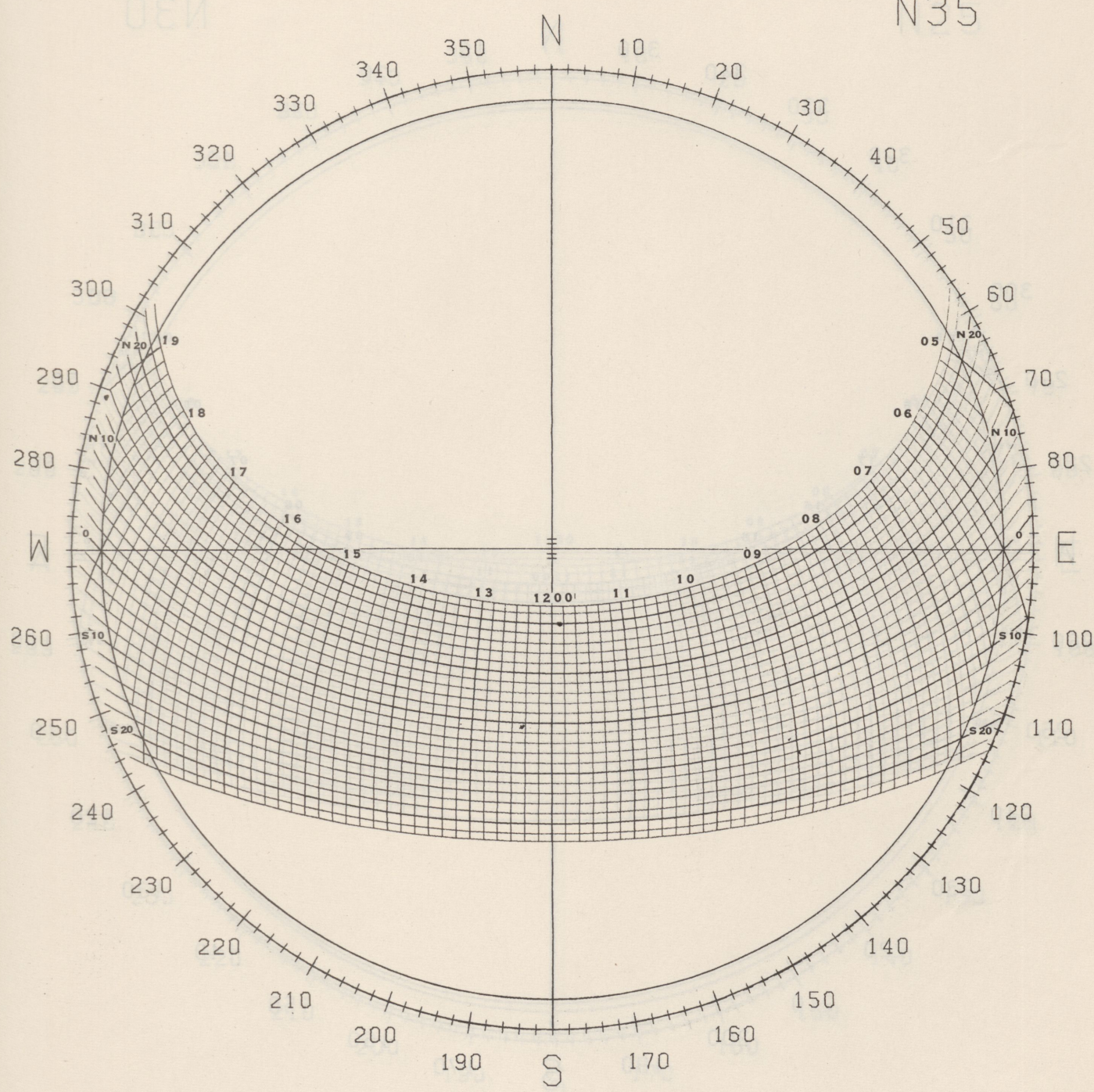


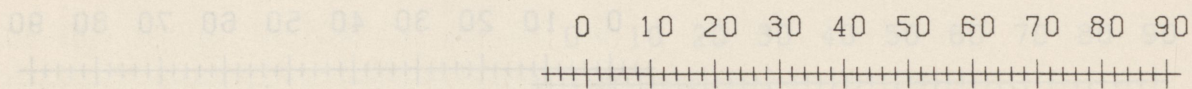
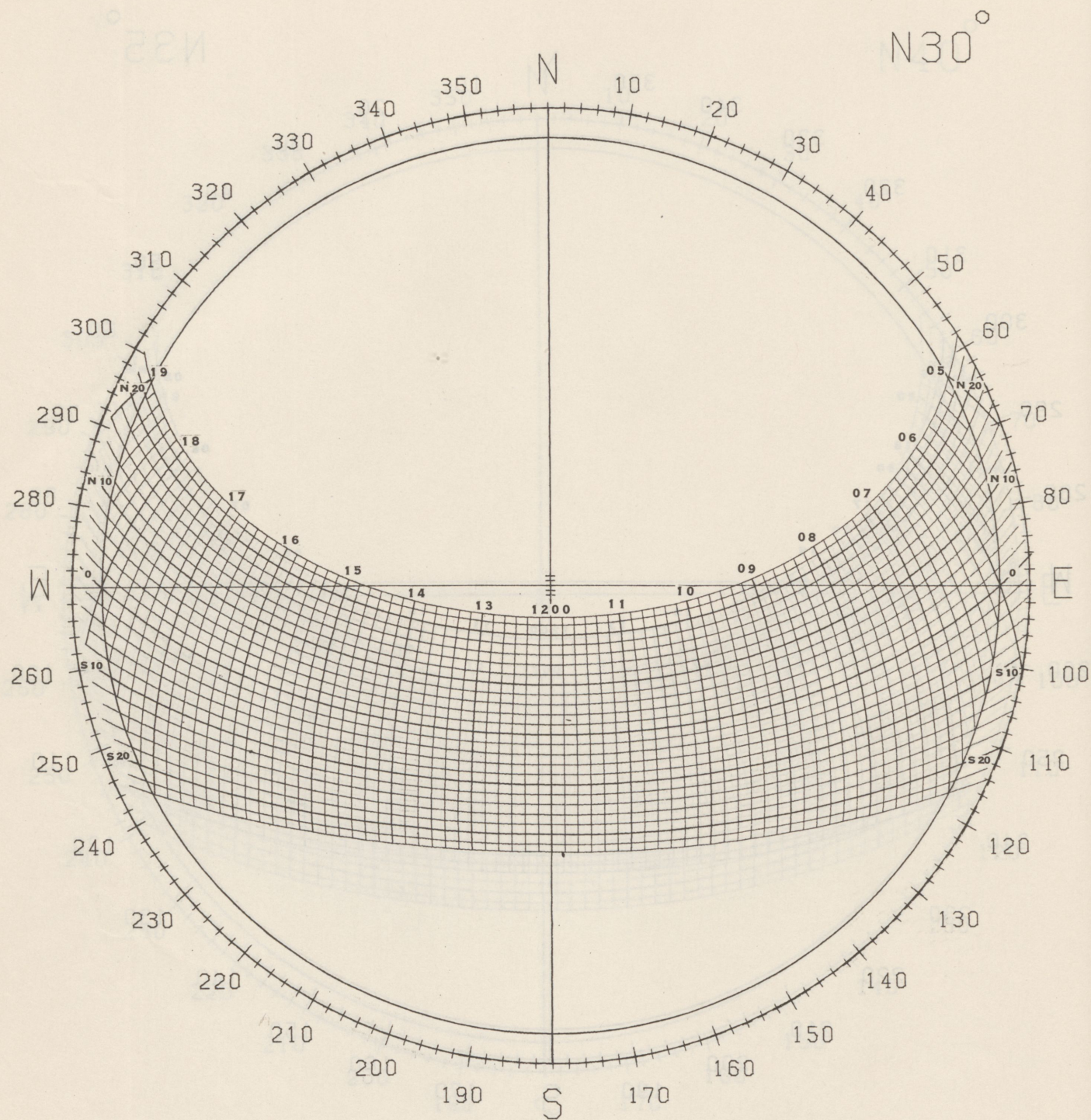




08N

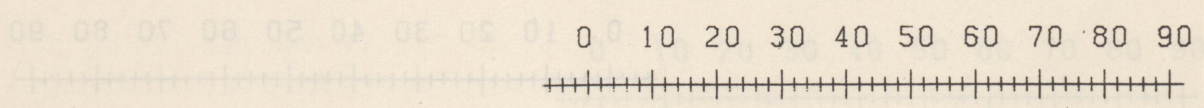
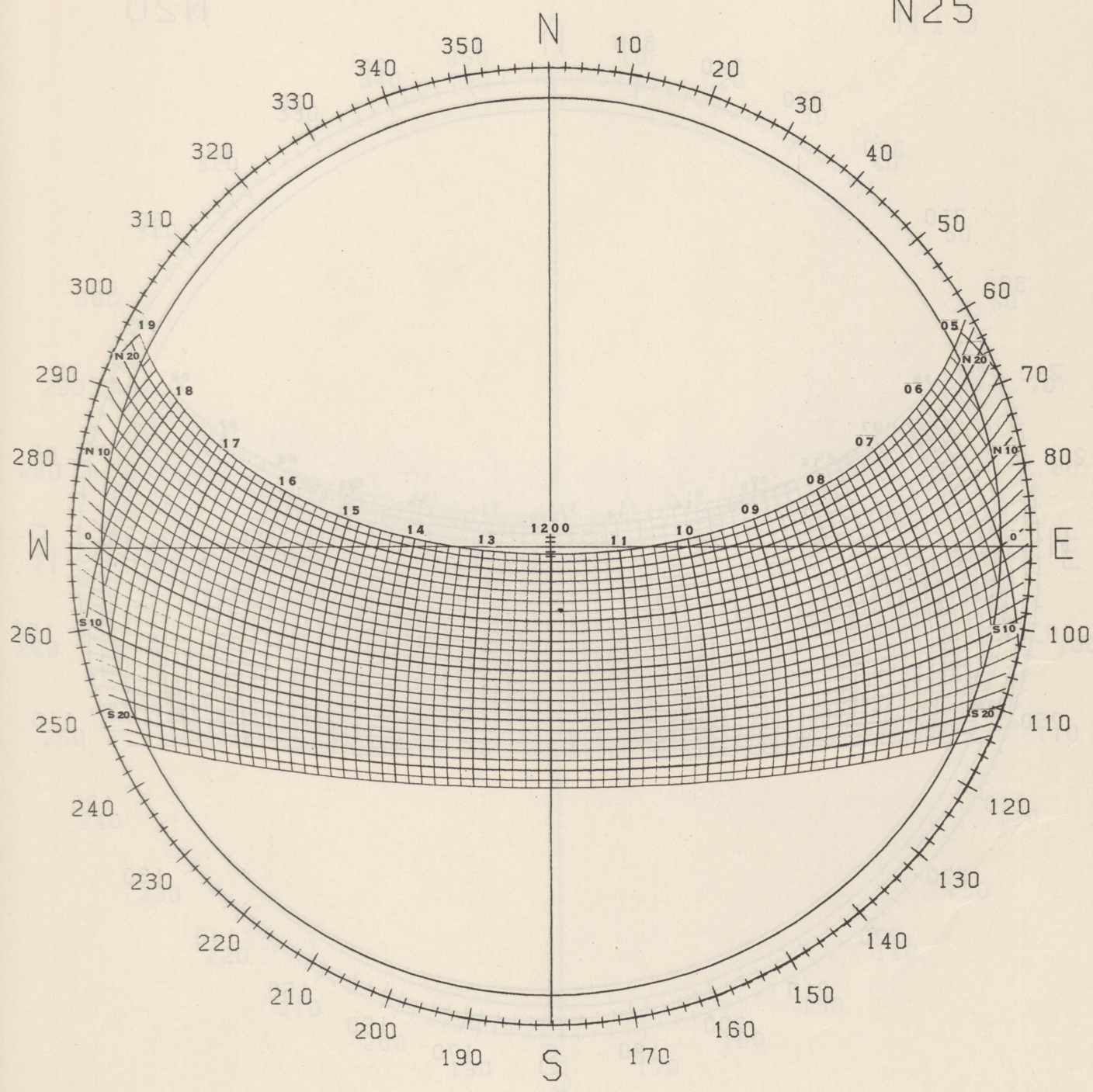
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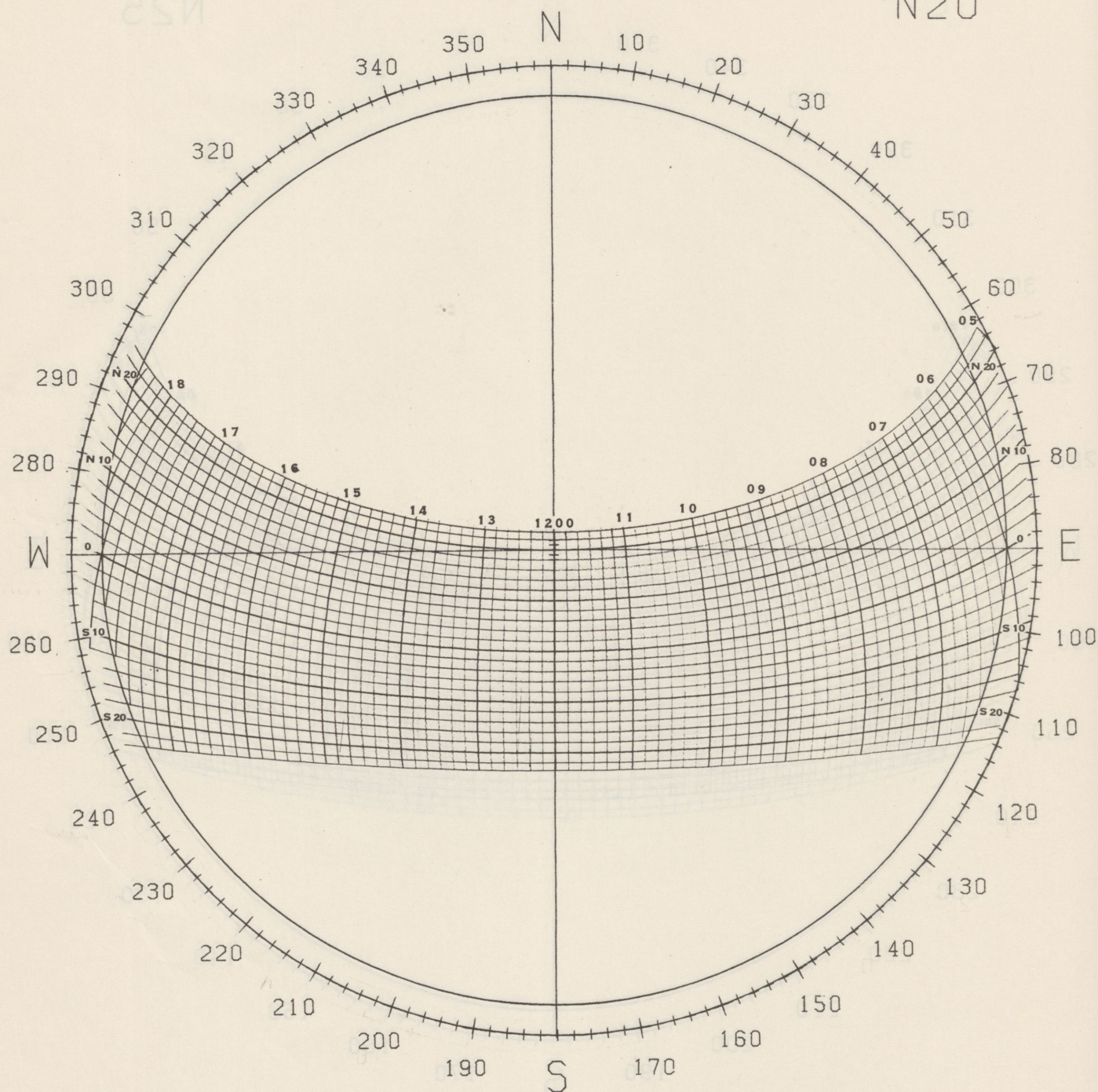


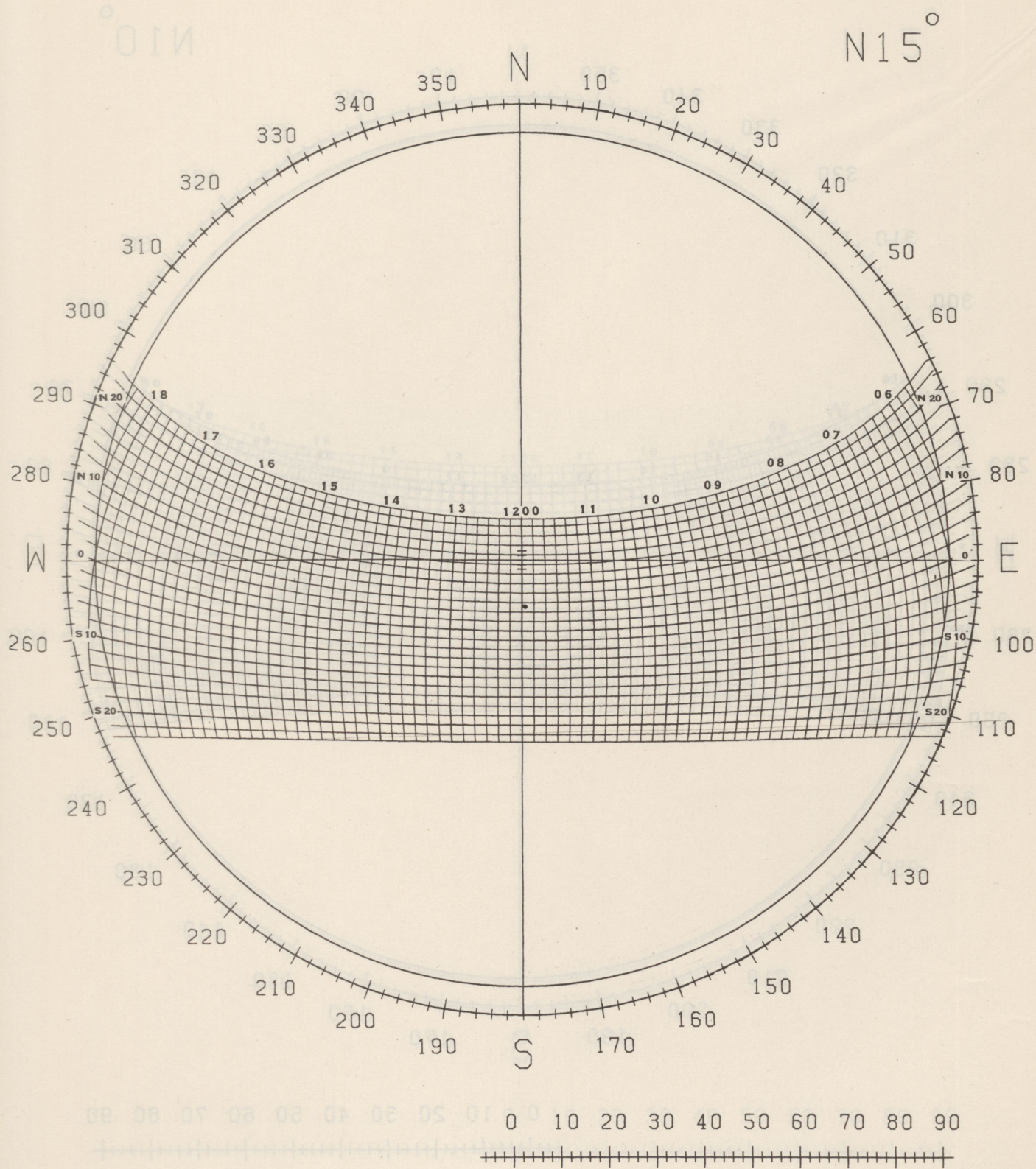
05N

N25°

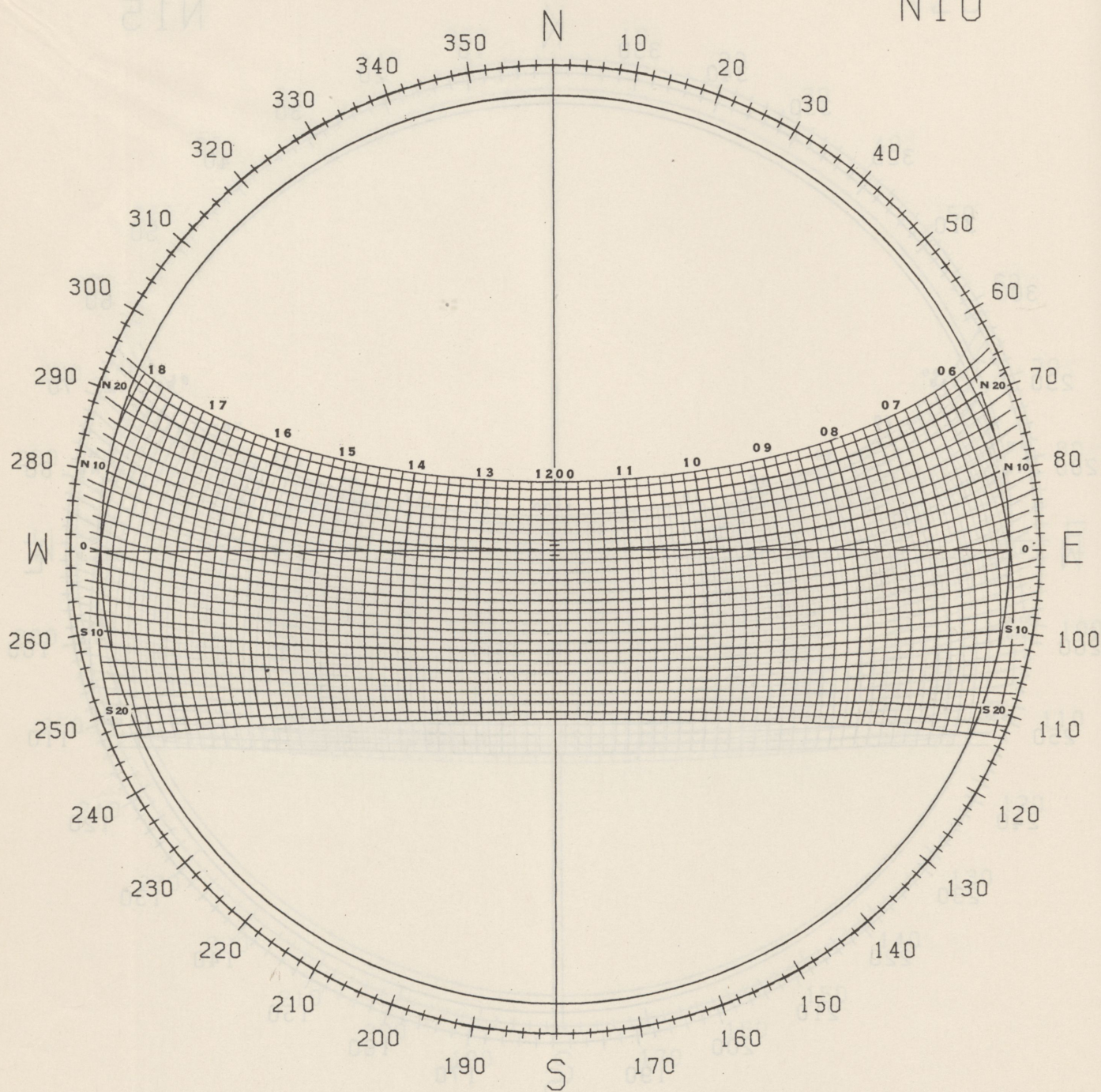


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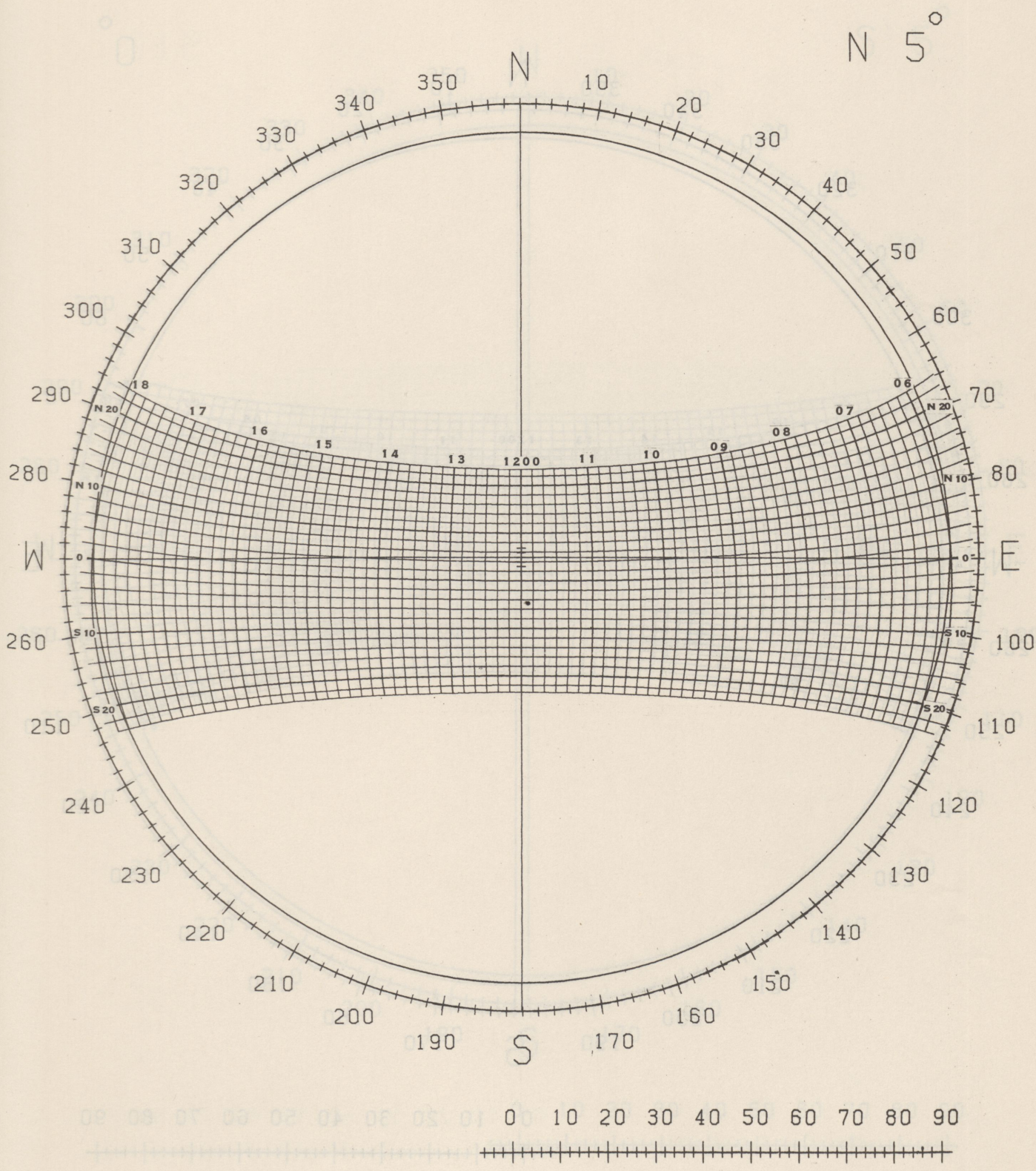




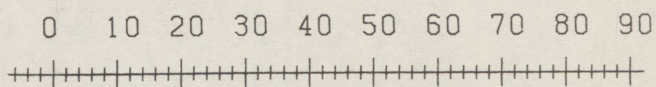
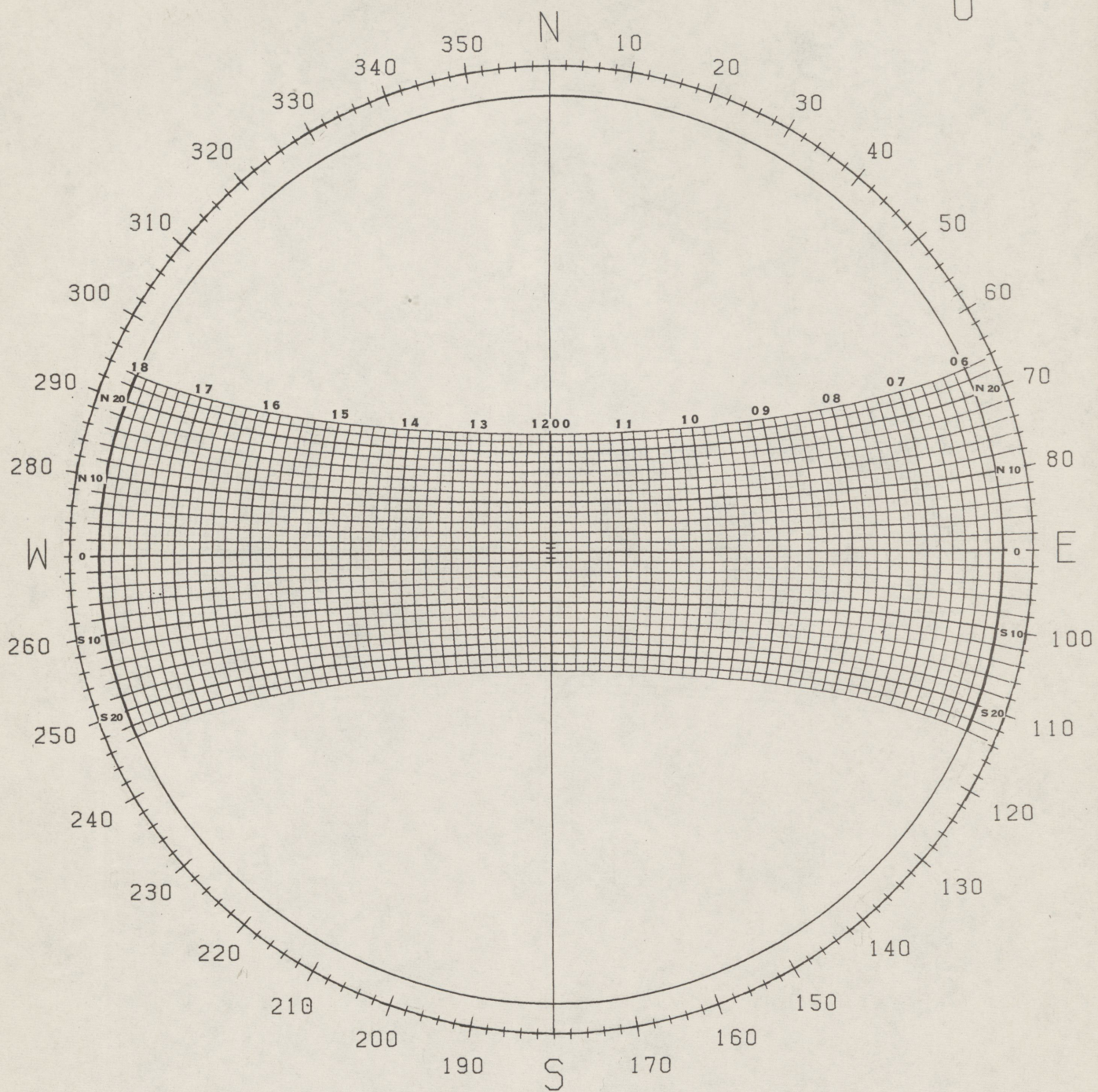
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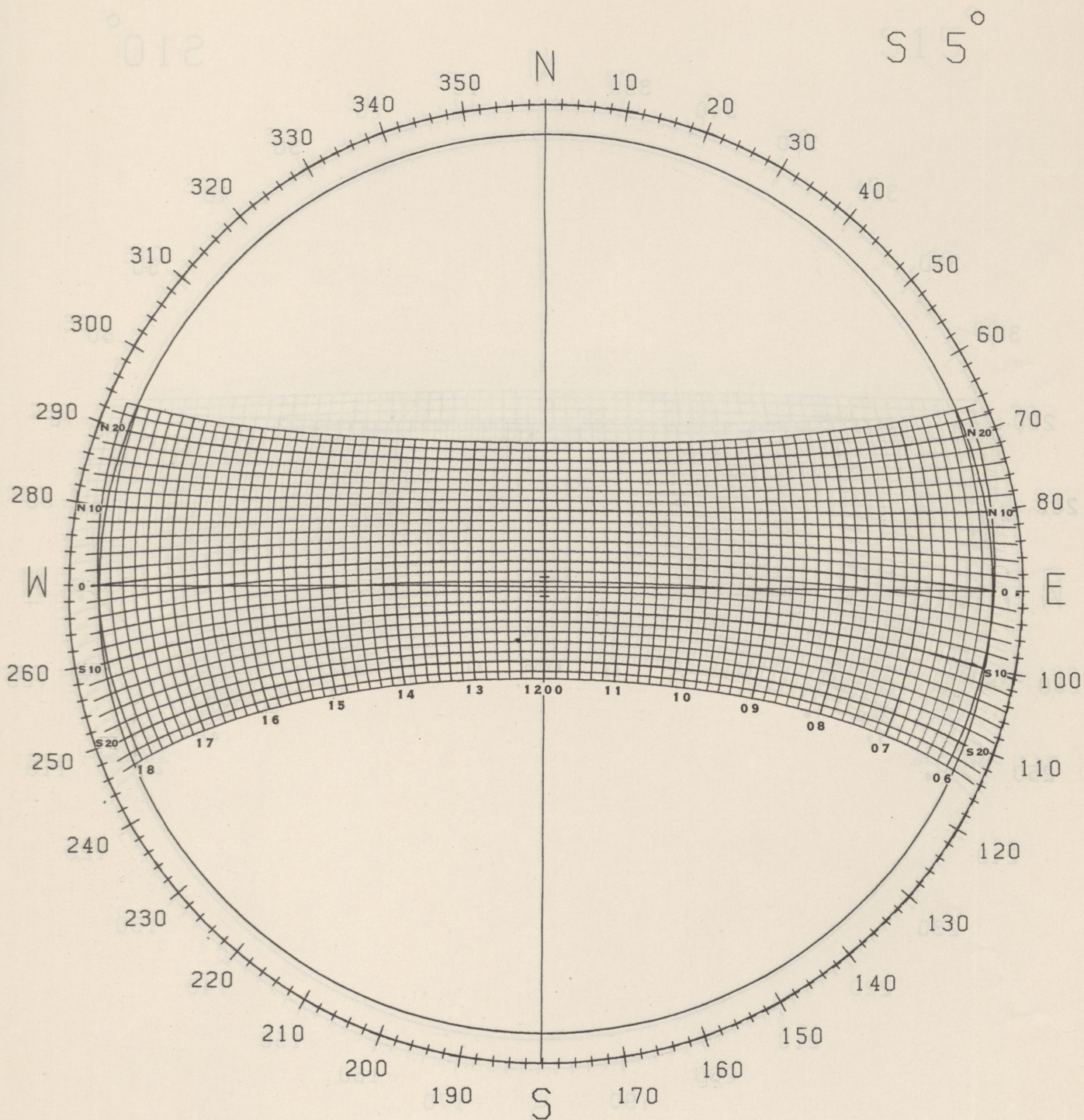


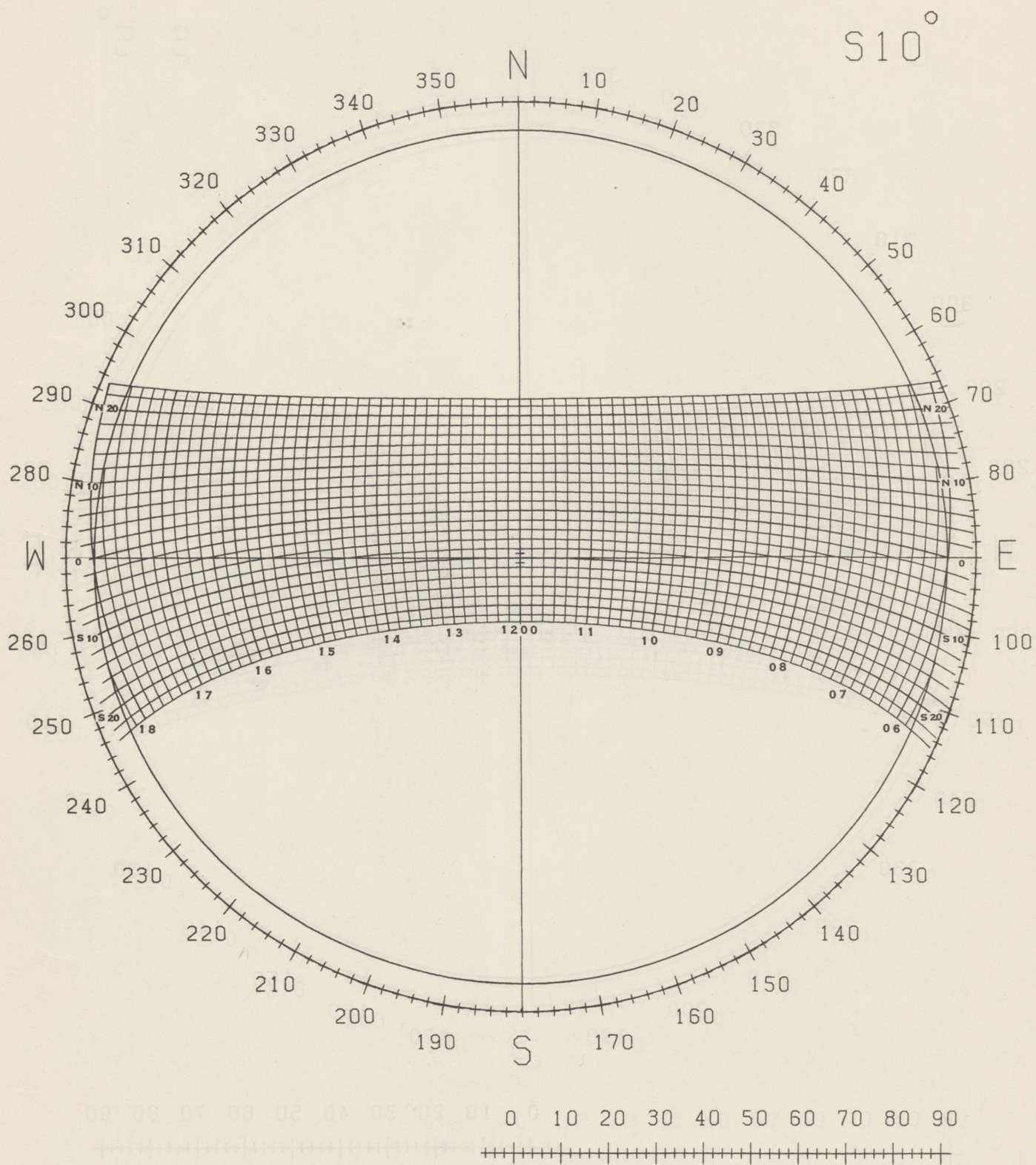
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0°

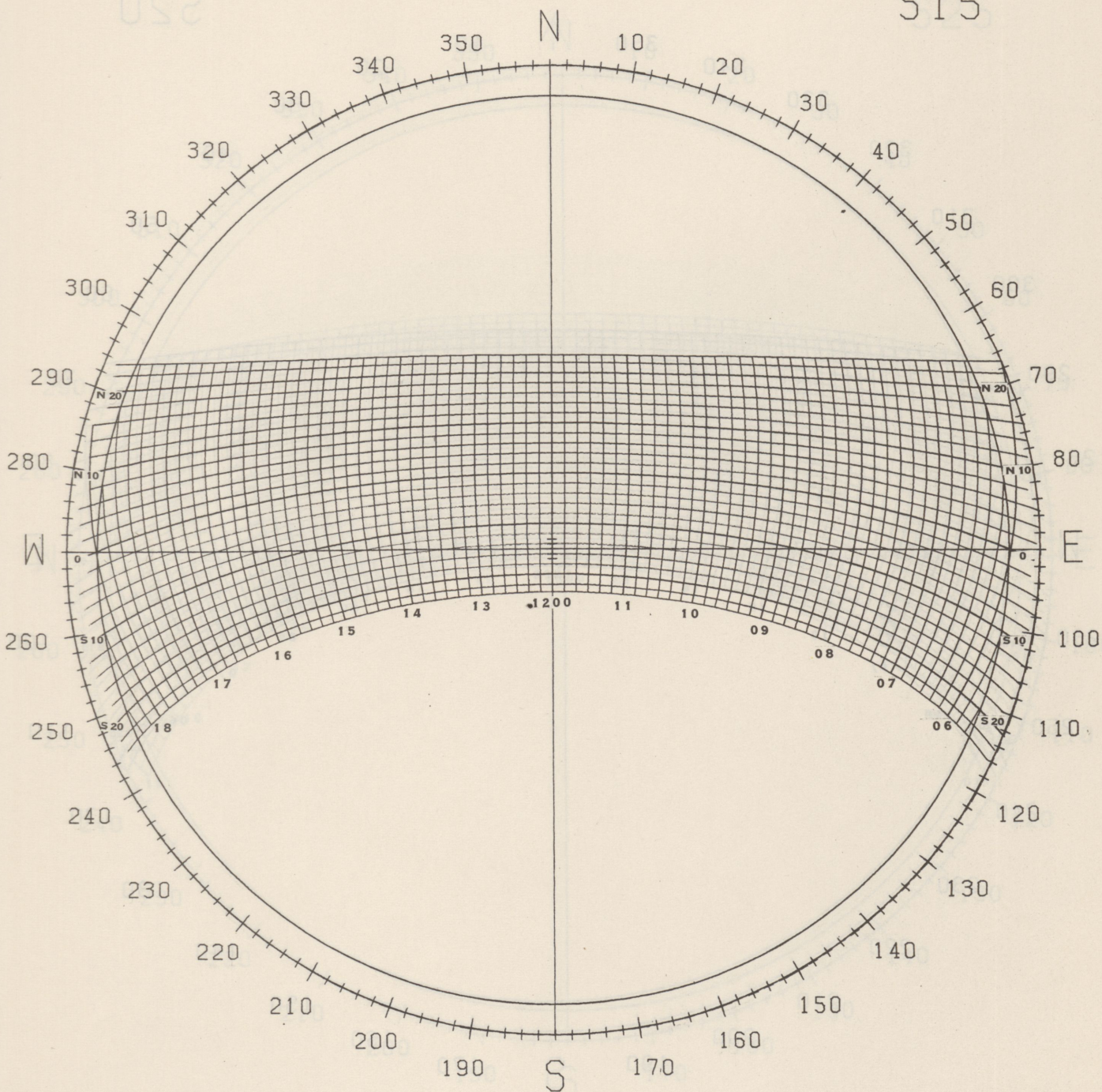




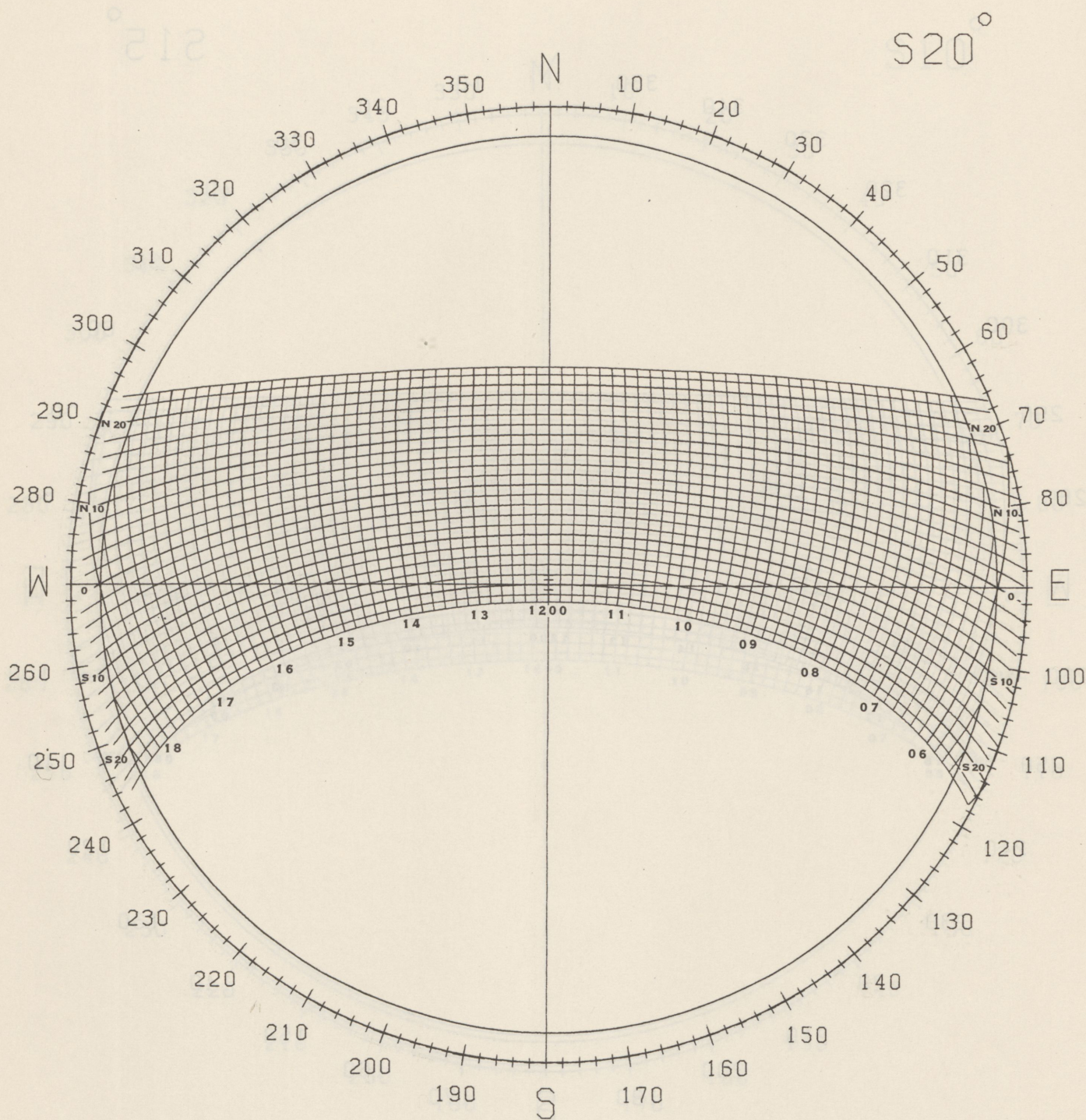


052

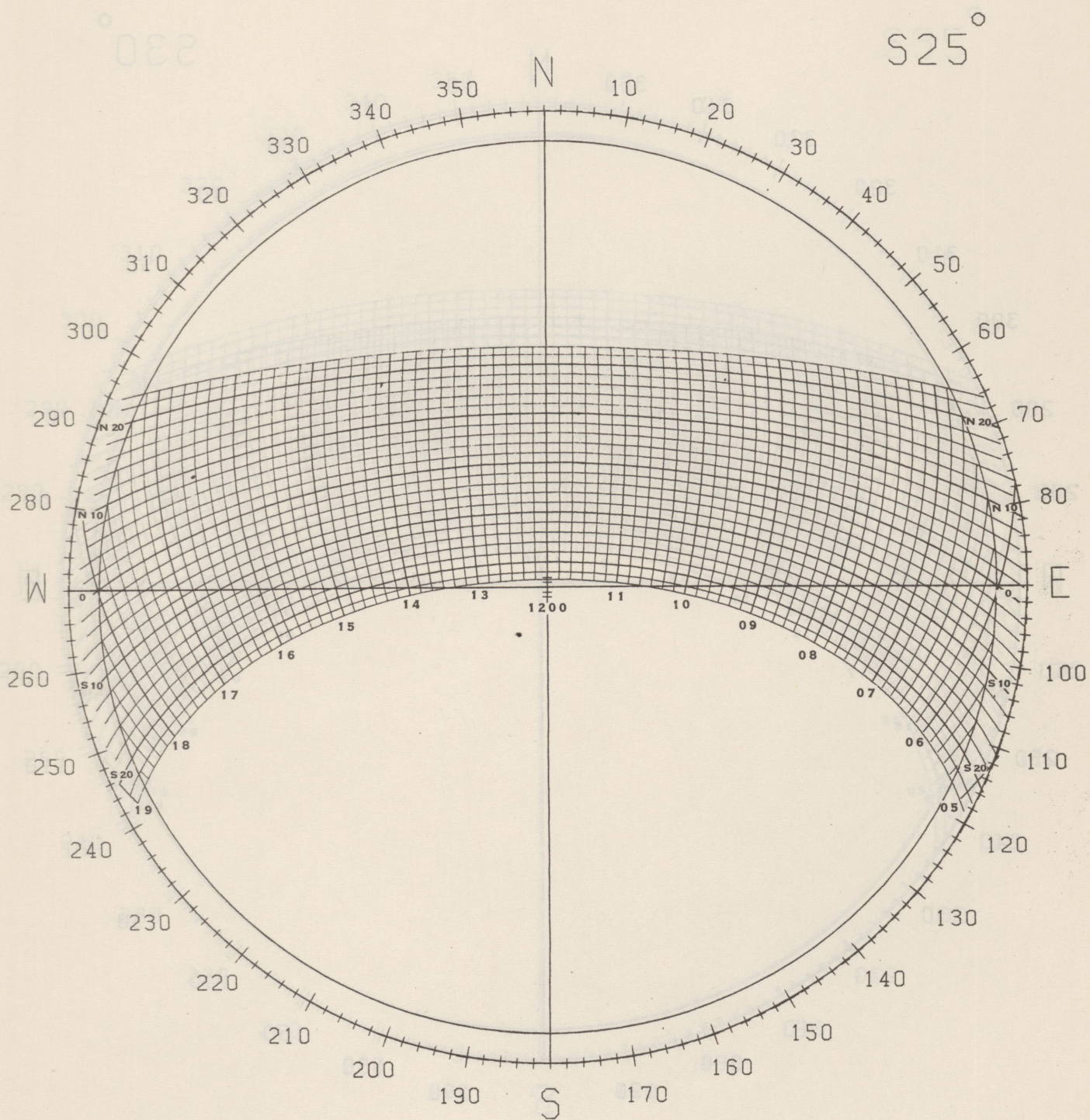
S15°



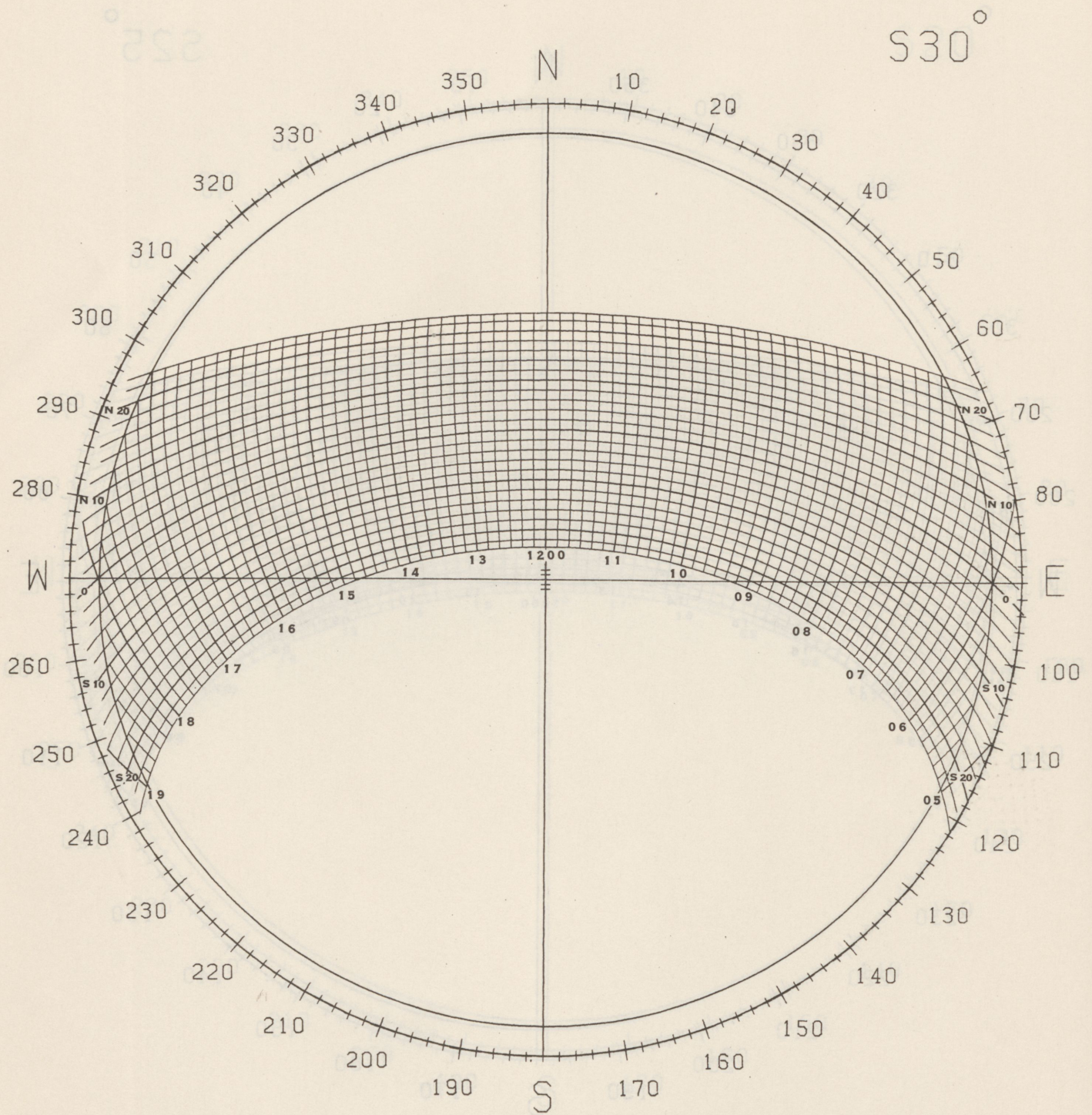
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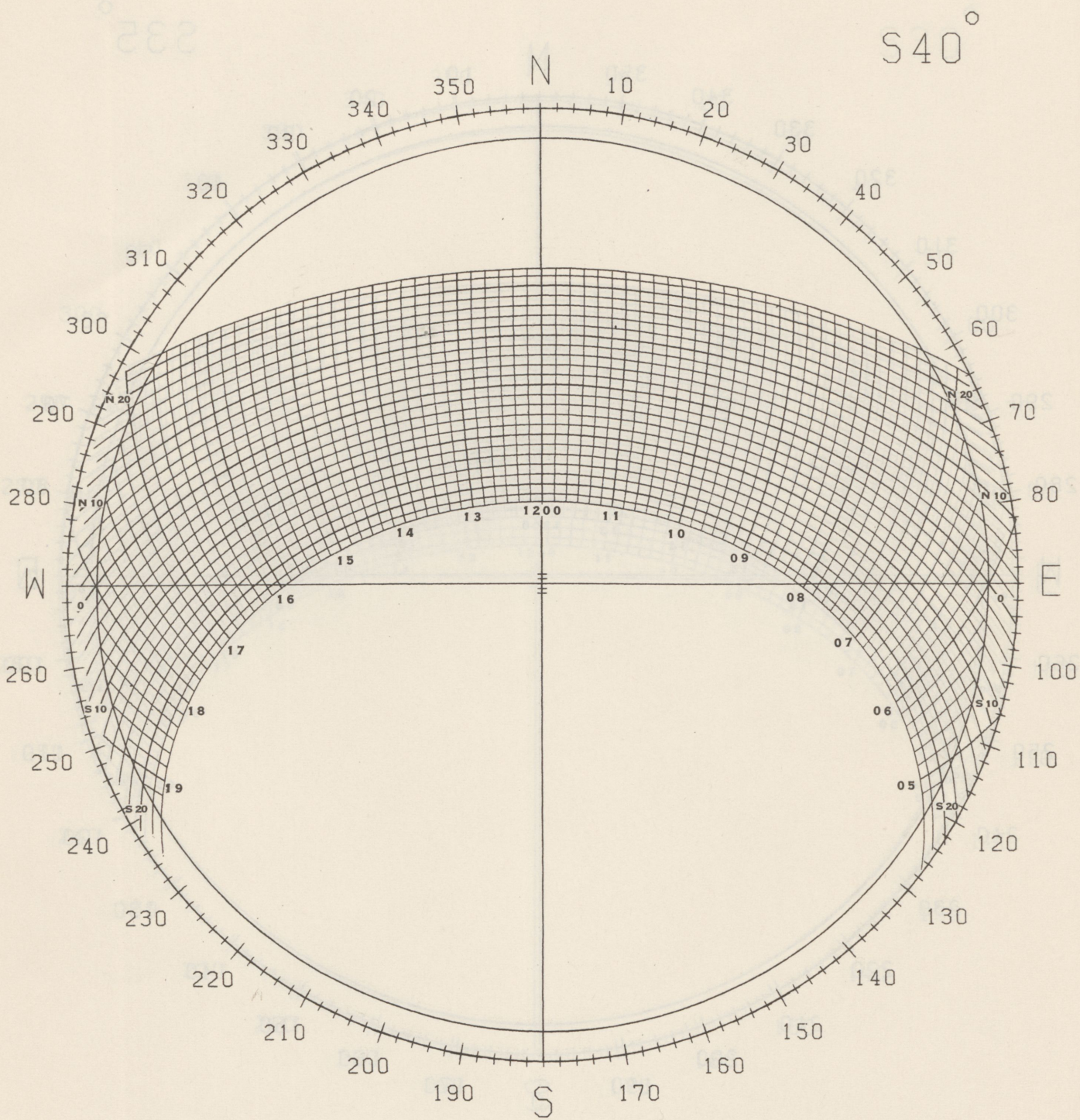


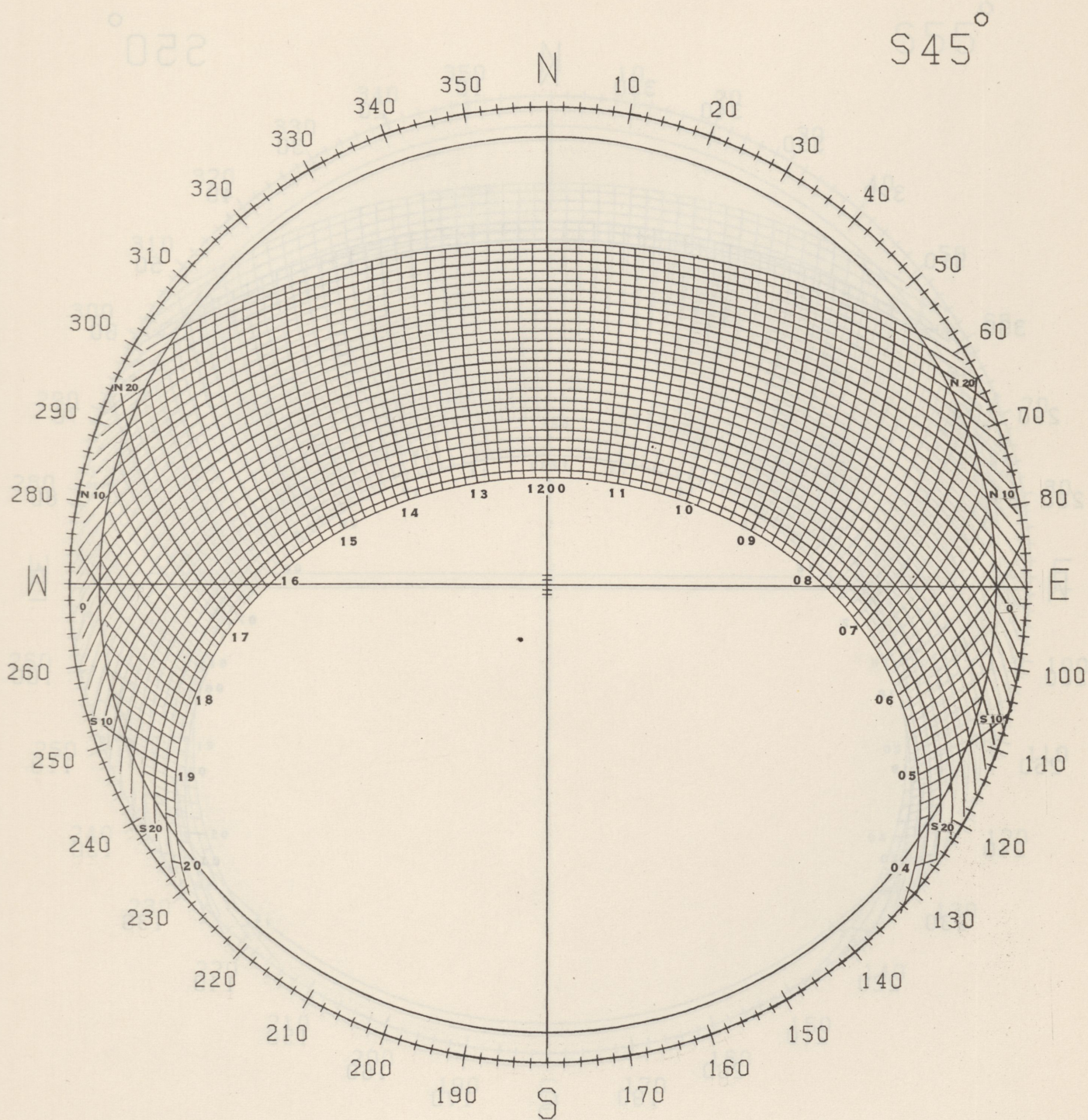
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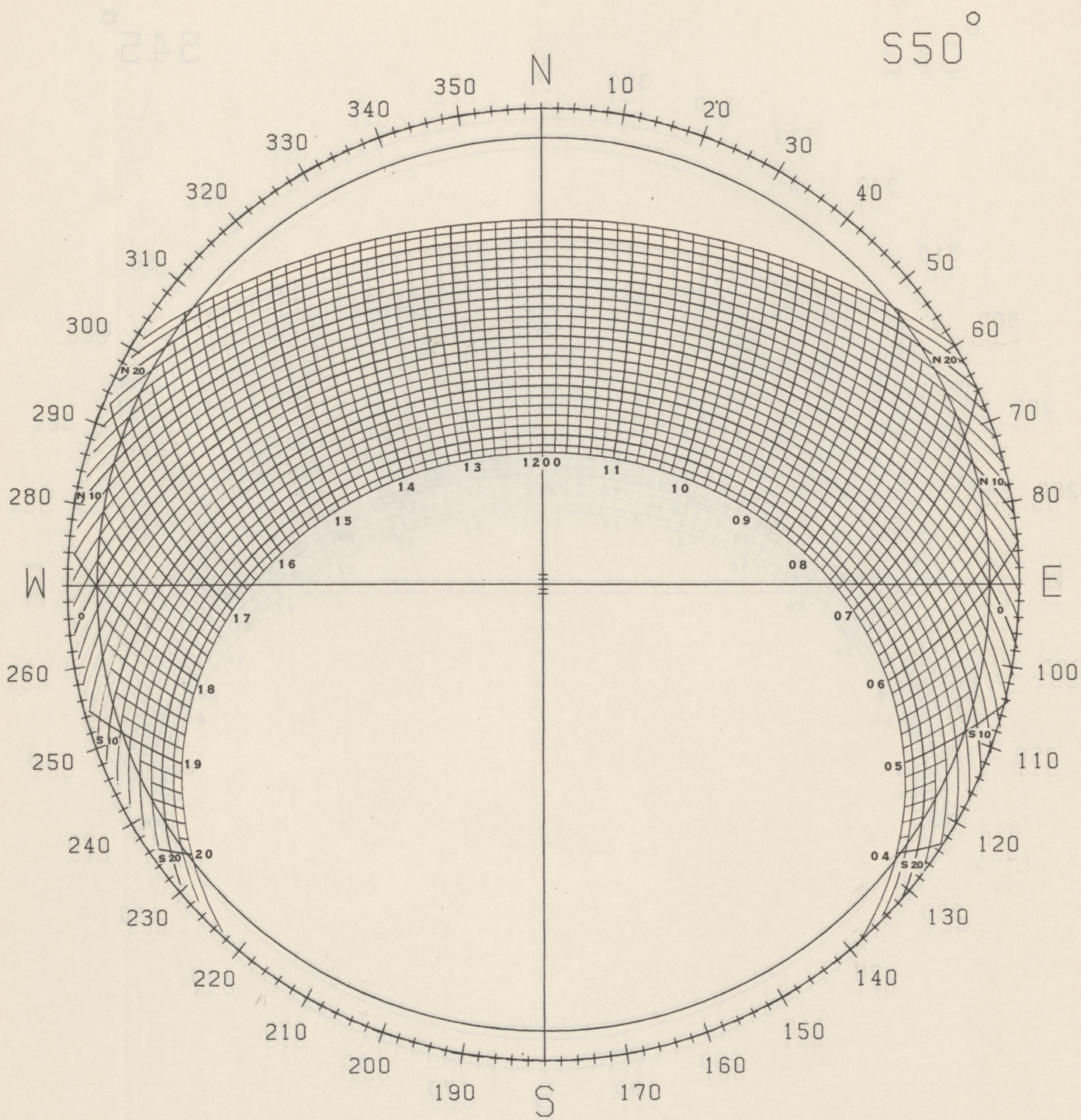


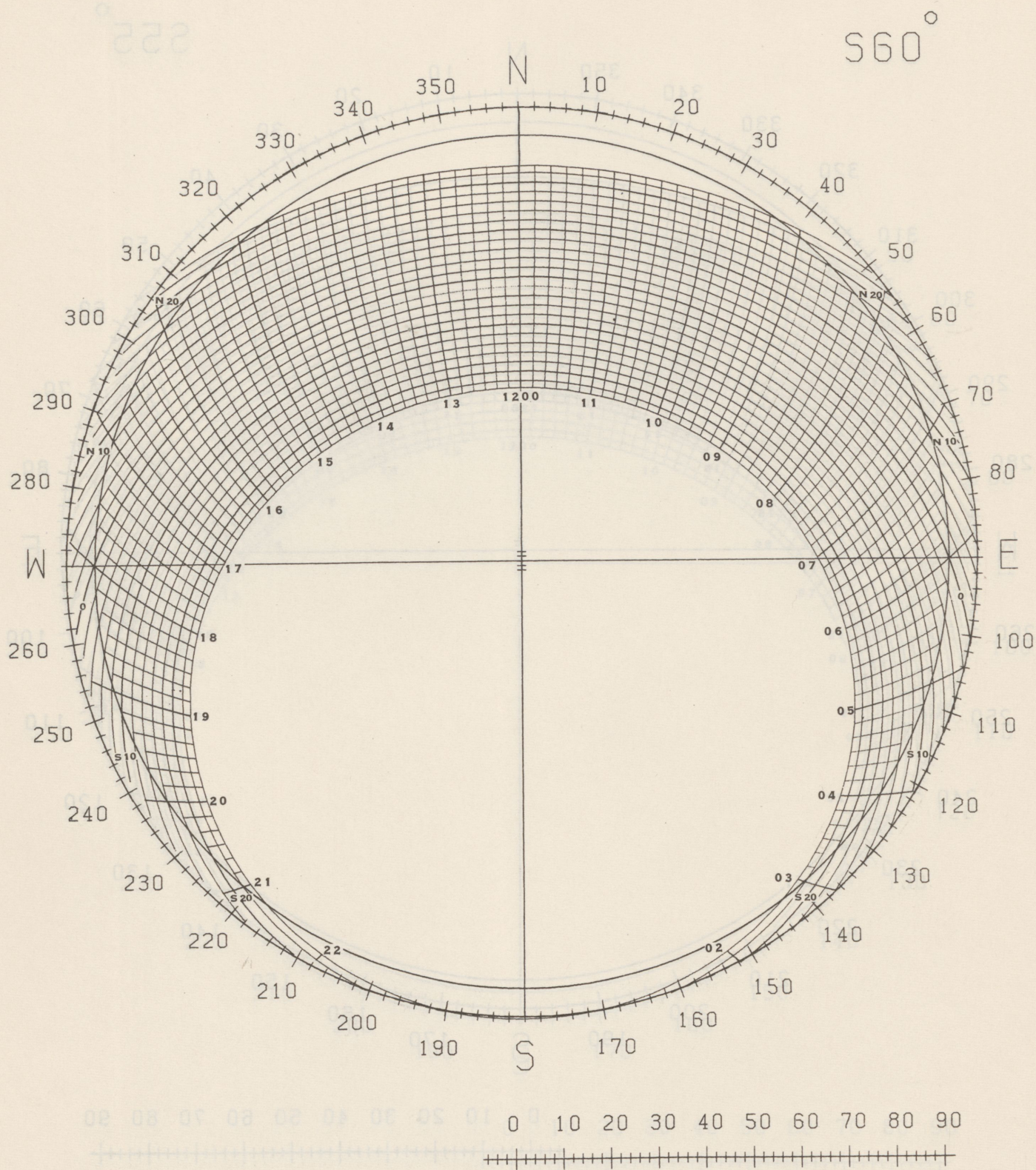
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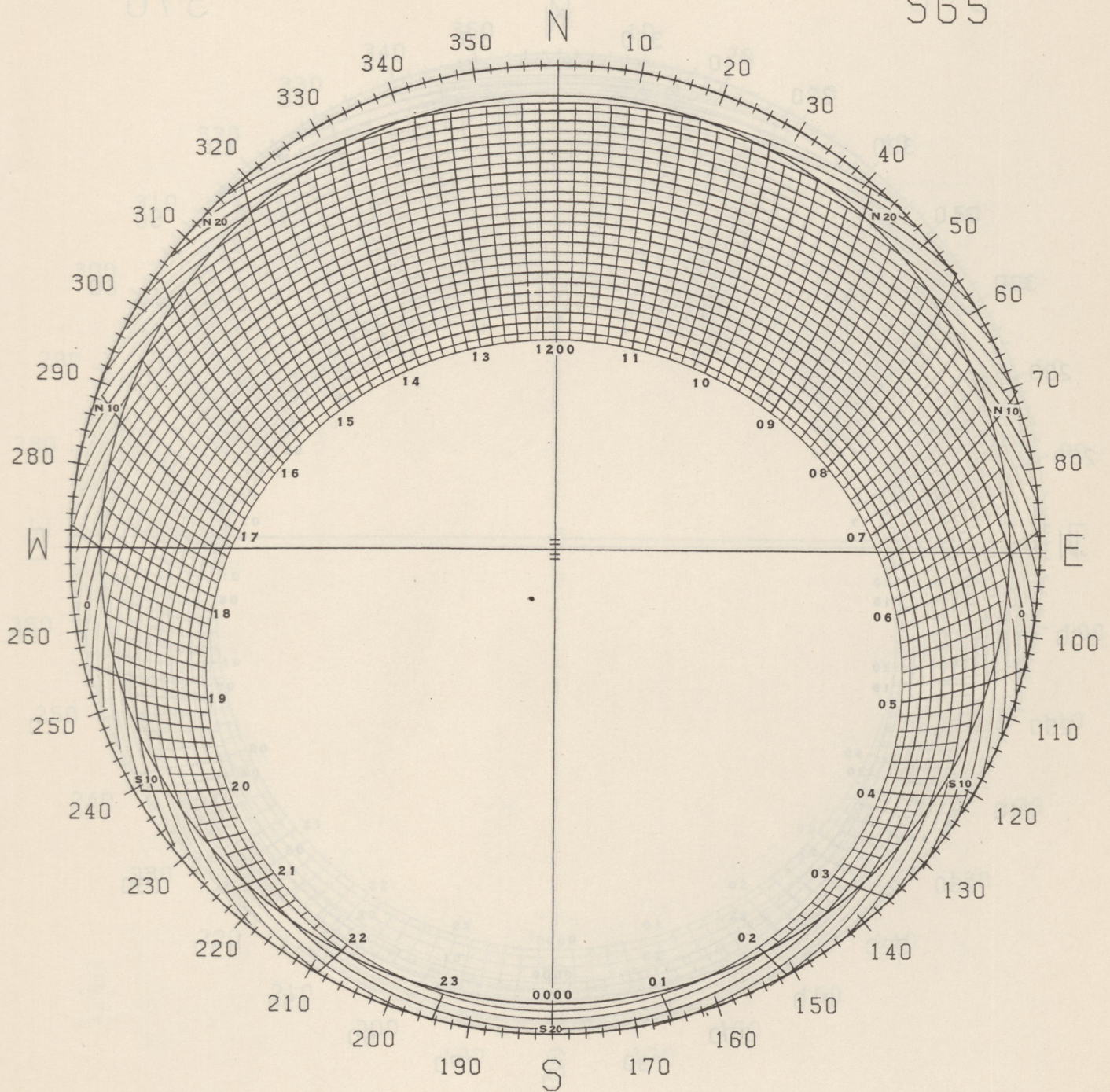




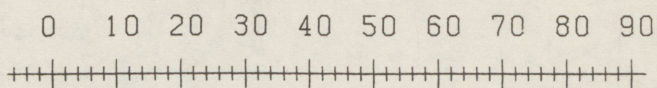
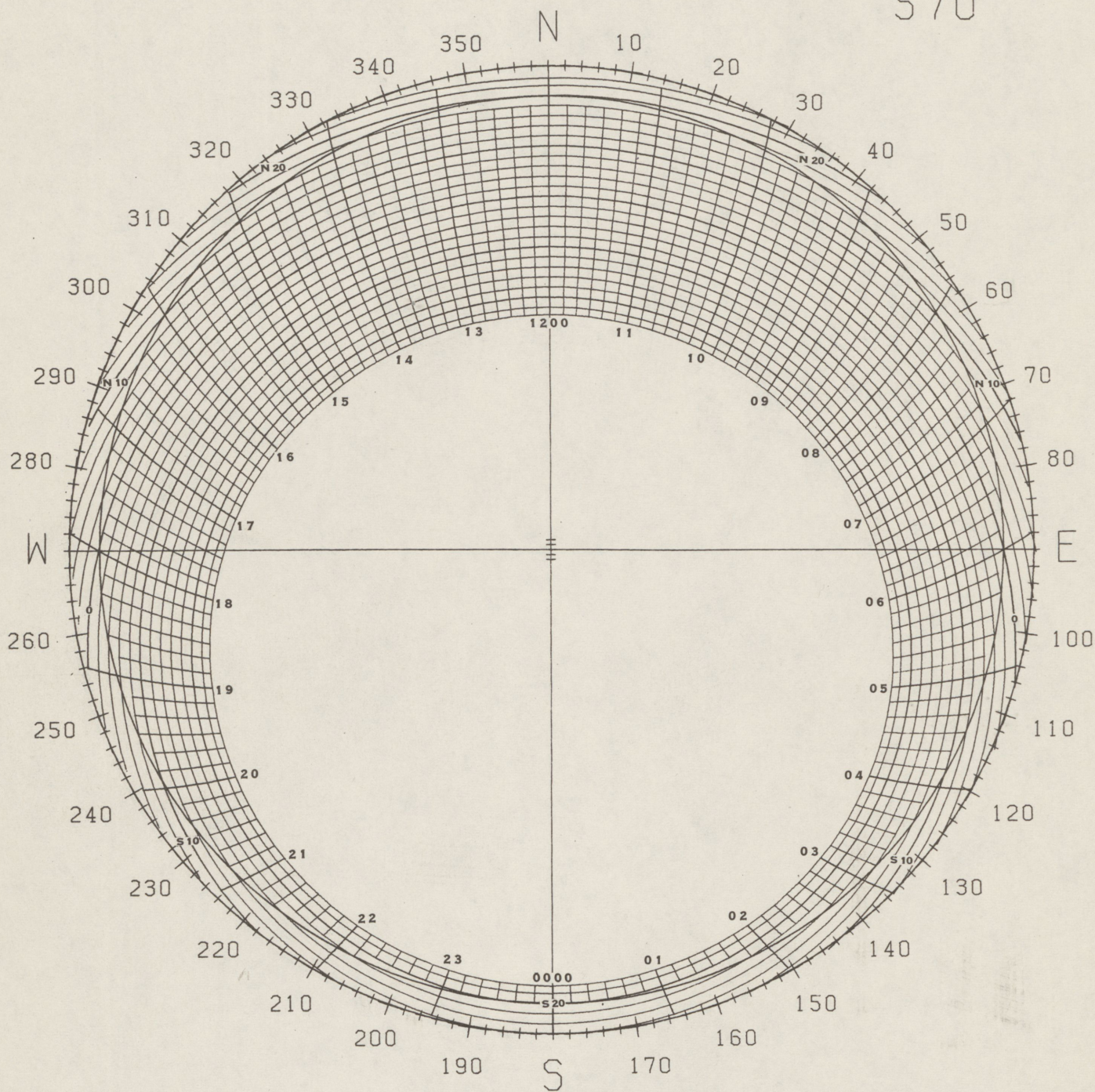


072

S65°

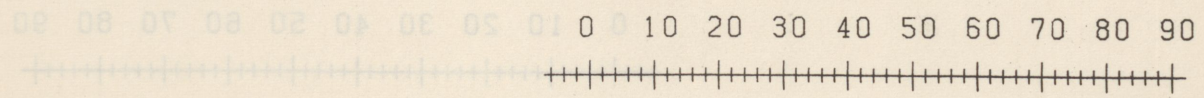
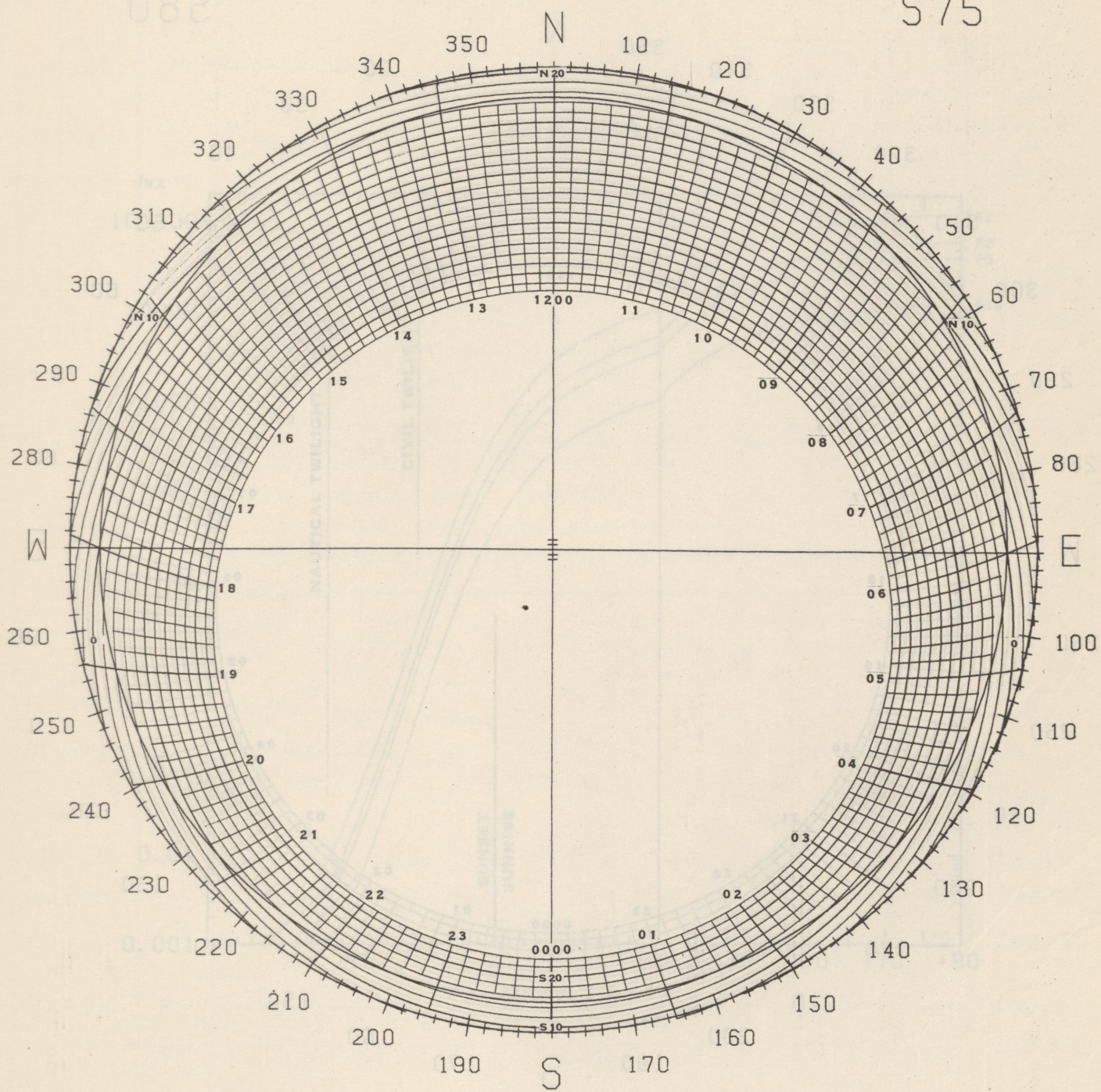


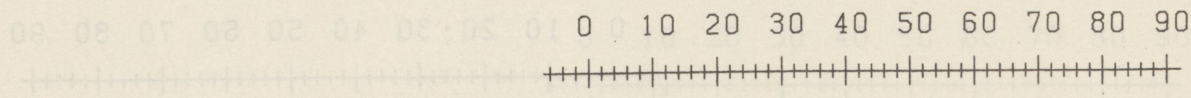
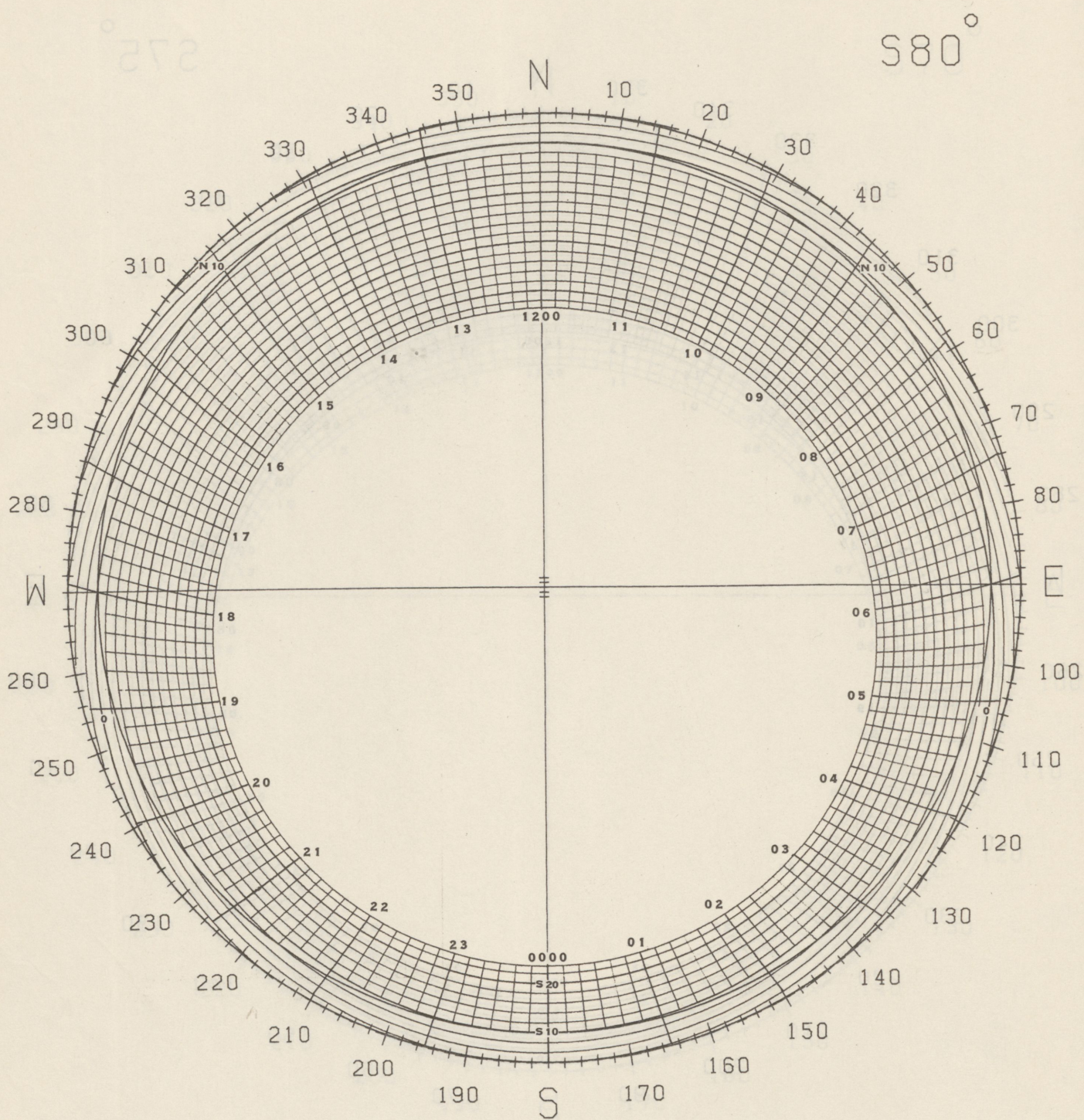
S70°



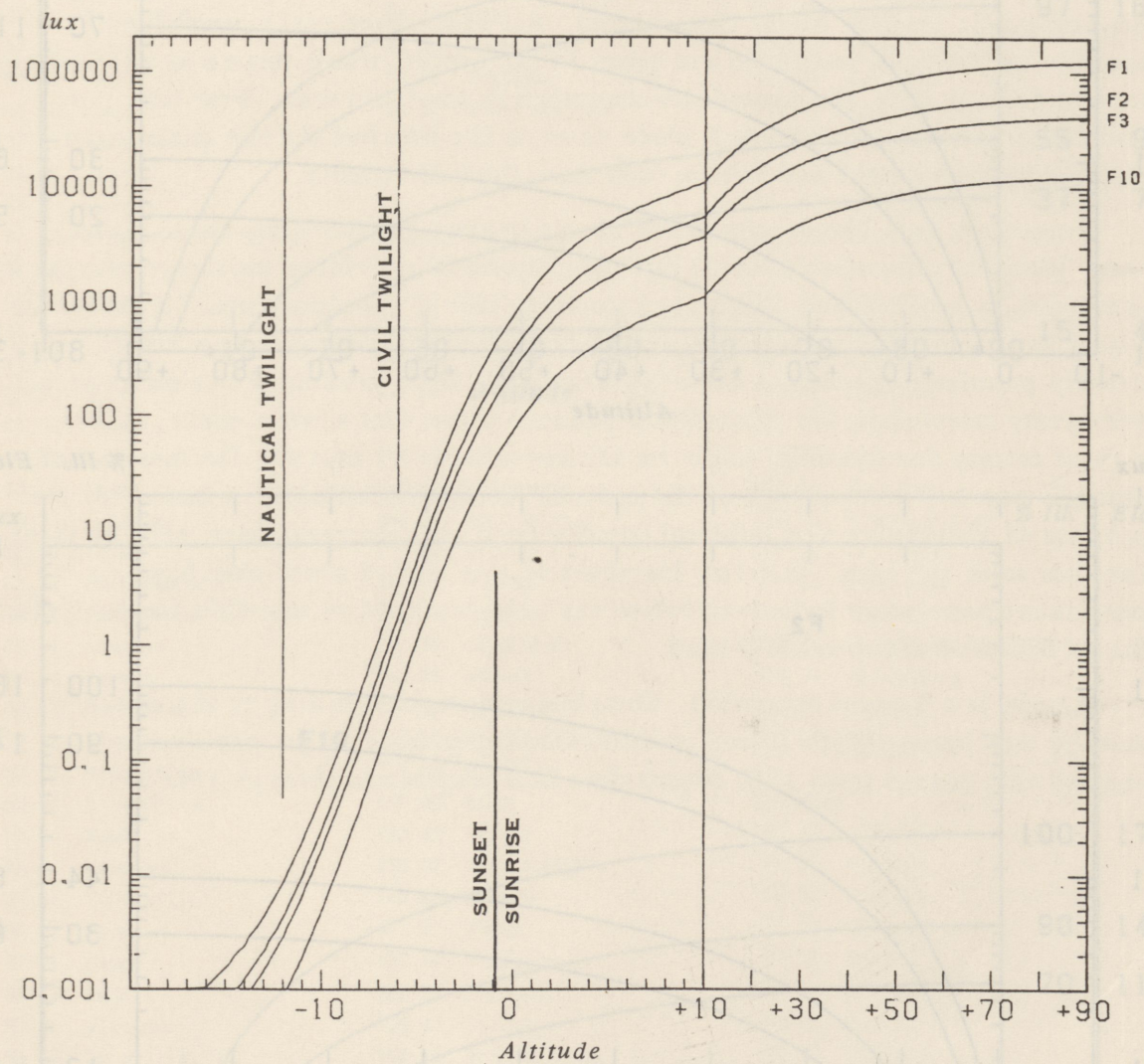
082

S75°

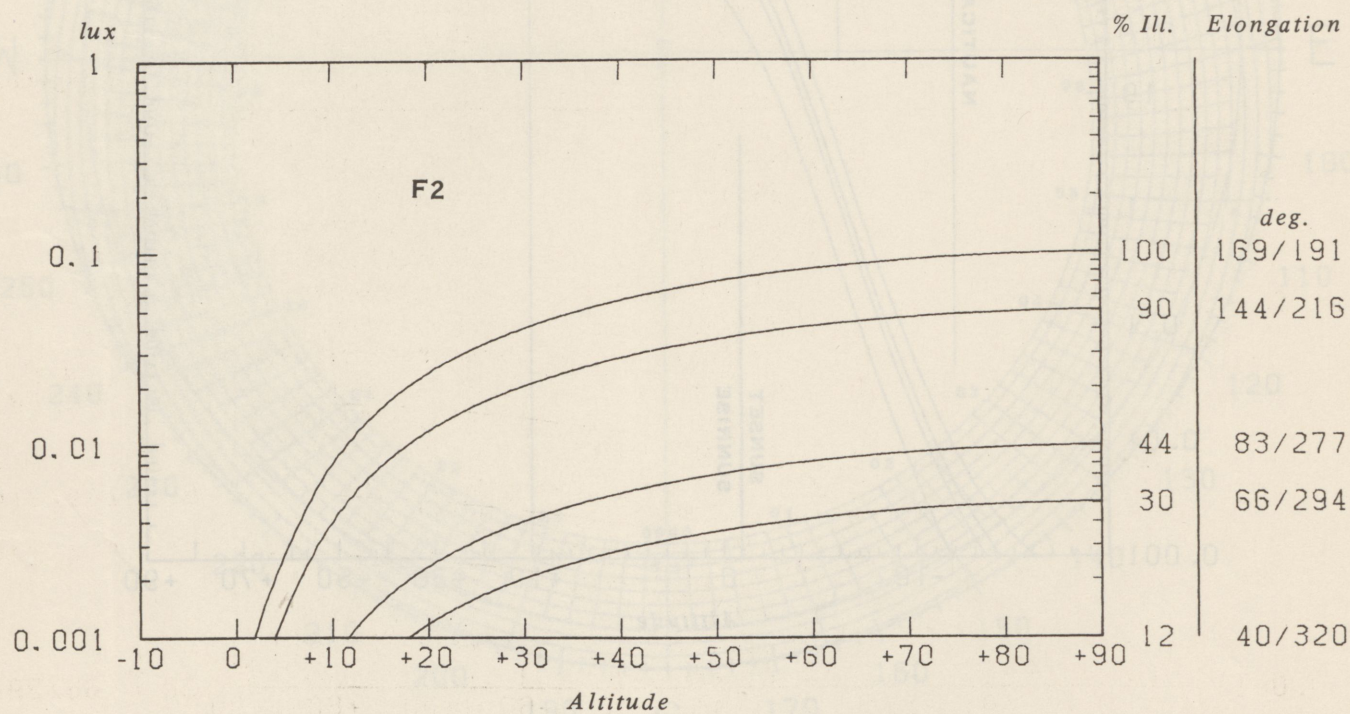
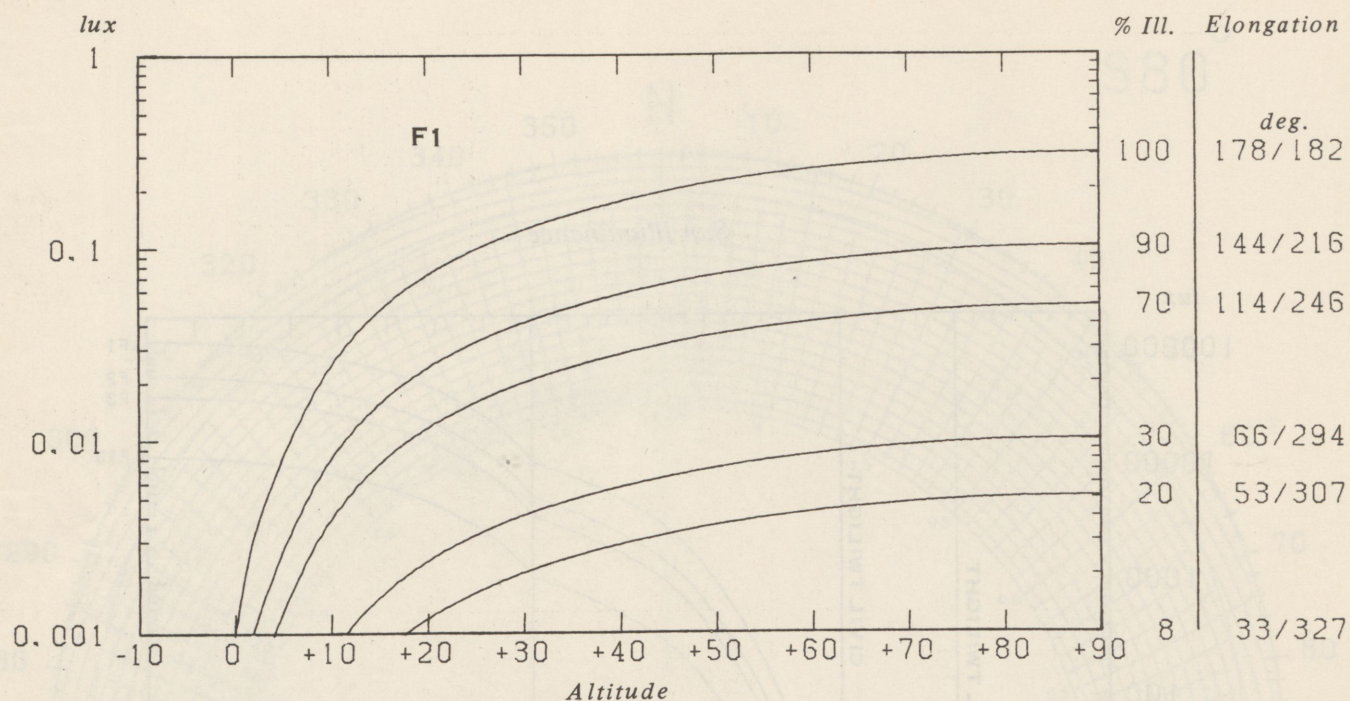




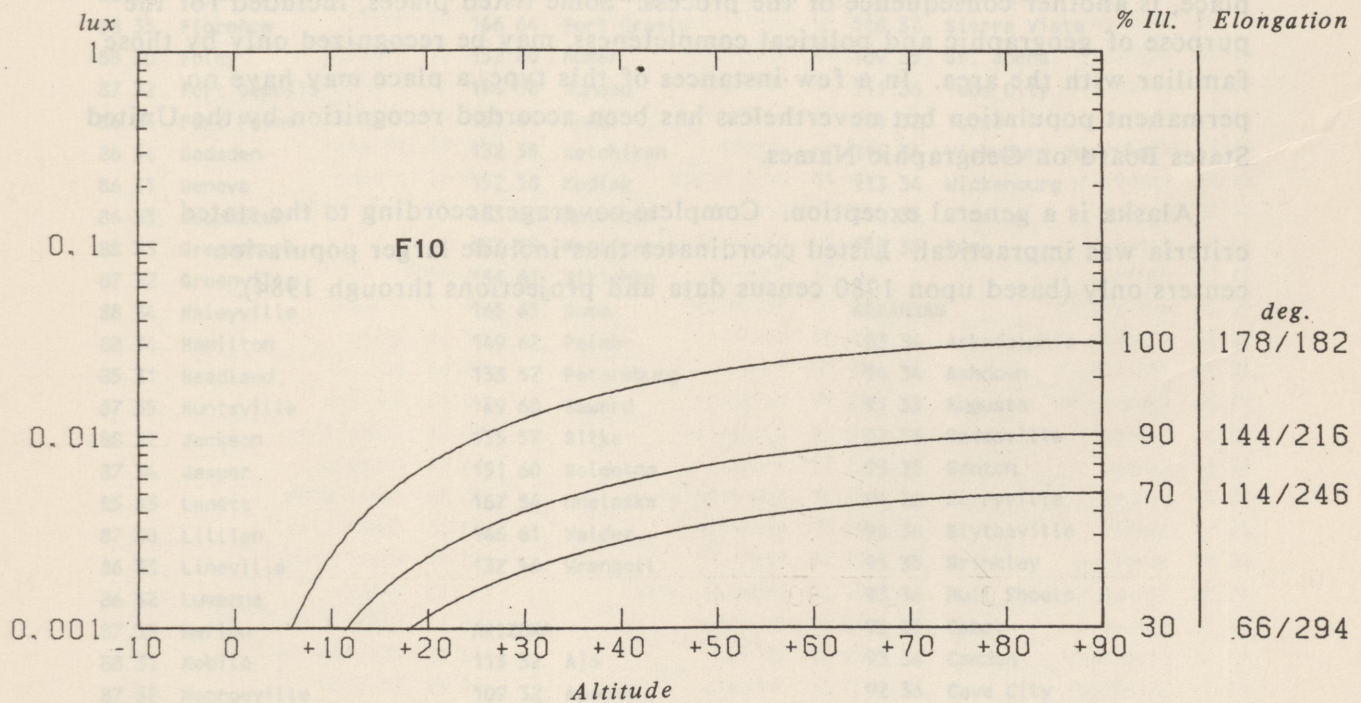
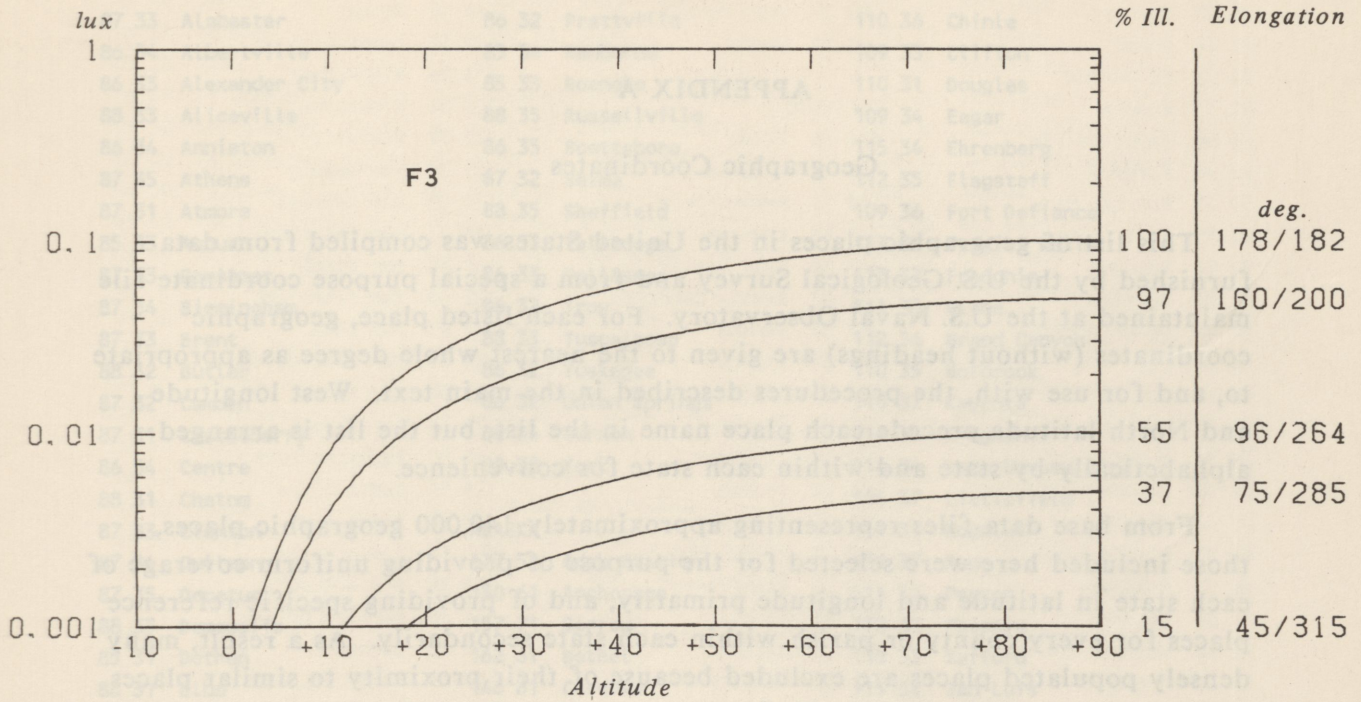
Sun Illuminance



Moon Illuminance



Moon Illuminance



APPENDIX A

Geographic Coordinates

This list of geographic places in the United States was compiled from data furnished by the U.S. Geological Survey and from a special purpose coordinate file maintained at the U.S. Naval Observatory. For each listed place, geographic coordinates (without headings) are given to the nearest whole degree as appropriate to, and for use with, the procedures described in the main text. West longitude and North latitude precede each place name in the list, but the list is arranged alphabetically by state and within each state for convenience.

From base data files representing approximately 140,000 geographic places, those included here were selected for the purpose of providing uniform coverage of each state in latitude and longitude primarily, and of providing specific reference places for every county or parish within each state secondarily. As a result, many densely populated places are excluded because of their proximity to similar places previously selected in the compilation process. Also, that a listed place, within a rural county for example, might be neither the county seat nor the most populous place, is another consequence of the process. Some listed places, included for the purpose of geographic and political completeness, may be recognized only by those familiar with the area. In a few instances of this type, a place may have no permanent population but nevertheless has been accorded recognition by the United States Board on Geographic Names.

Alaska is a general exception. Complete coverage according to the stated criteria was impractical. Listed coordinates thus include larger population centers only (based upon 1980 census data and projections through 1984).

ALABAMA

87 33 Alabaster
 86 34 Albertville
 86 33 Alexander City
 88 33 Aliceville
 86 34 Anniston
 87 35 Athens
 87 31 Atmore
 85 33 Auburn
 87 33 Bessemer
 87 34 Birmingham
 87 33 Brent
 88 32 Butler
 87 32 Camden
 87 31 Castleberry
 86 34 Centre
 88 31 Chatom
 87 33 Clanton
 87 34 Cullman
 87 35 Decatur
 88 33 Demopolis
 85 31 Dothan
 86 31 Elba
 85 32 Eufaula
 88 33 Eutaw
 88 34 Fayette
 88 35 Florence
 88 30 Foley
 87 32 Fort Deposit
 86 34 Fort Payne
 86 34 Gadsden
 86 31 Geneva
 86 33 Goodwater
 88 33 Greensboro
 87 32 Greenville
 88 34 Haleyville
 88 34 Hamilton
 85 31 Headland
 87 35 Huntsville
 88 32 Jackson
 87 34 Jasper
 85 33 Lanett
 87 30 Lillian
 86 33 Lineville
 86 32 Luverne
 87 33 Marion
 88 31 Mobile
 87 32 Monroeville
 86 32 Montgomery
 87 34 Moulton
 86 34 Oneonta
 86 31 Opp
 86 31 Ozark
 86 34 Pell City

85 32 Phenix City
 86 32 Prattville
 85 34 Ranburne
 85 33 Roanoke
 88 35 Russellville
 86 35 Scottsboro
 87 32 Selma
 88 35 Sheffield
 86 33 Talladega
 86 33 Tallassee
 86 32 Troy
 88 33 Tuscaloosa
 86 32 Tuskegee
 86 32 Union Springs
 88 34 Vernon
 88 32 York

ALASKA

177 52 Adak Station
 150 61 Anchorage
 157 71 Barrow
 162 61 Bethel
 146 61 Cordova
 158 59 Dillingham
 147 65 Eielson
 148 65 Fairbanks
 146 64 Fort Greely
 152 60 Homer
 134 58 Juneau
 151 61 Kenai
 132 55 Ketchikan
 152 58 Kodiak
 163 67 Kotzebue
 132 55 Metlakatla
 151 61 Nikishka
 165 65 Nome
 149 62 Palmer
 133 57 Petersburg
 149 60 Seward
 135 57 Sitka
 151 60 Soldotna
 167 54 Unalaska
 146 61 Valdez
 132 56 Wrangell

ARIZONA

113 32 Ajo
 109 32 Apache
 113 35 Bagdad
 115 35 Berry
 109 37 Bitlabito
 114 36 Bonelli Landing
 113 33 Buckeye
 112 33 Casa Grande

109 31 Cazador
 110 36 Chinle
 109 33 Clifton
 110 31 Douglas
 109 34 Eagar
 115 34 Ehrenberg
 112 35 Flagstaff
 109 36 Fort Defiance
 113 36 Frazier Wells
 113 37 Fredonia
 111 33 Globe
 112 36 Grand Canyon
 110 35 Holbrook
 110 37 Kayenta
 114 35 Kingman
 114 34 Lake Havasu City
 114 37 Littlefield
 111 31 Nogales
 111 37 Page
 111 34 Payson
 112 33 Phoenix
 110 33 Safford
 115 32 San Luis
 112 31 Sasabe
 112 32 Sells
 110 34 Show Low
 110 32 Sierra Vista
 109 35 St. Johns
 111 36 Tuba City
 111 32 Tucson
 114 34 Vicksburg Junction
 113 34 Wickenburg
 111 35 Winslow
 115 33 Yuma

ARKANSAS

93 34 Arkadelphia
 94 34 Ashdown
 91 35 Augusta
 92 36 Batesville
 93 35 Benton
 94 36 Berryville
 90 36 Blytheville
 91 35 Brinkley
 93 36 Bull Shoals
 92 35 Cabot
 93 34 Camden
 92 36 Cave City
 93 35 Clarksville
 92 36 Clinton
 92 35 Conway
 93 36 Cotter
 92 33 Crossett
 93 35 Dardanelle

94 34	De Queen	91 35	West Helena	122 41	Redding
91 35	Des Arc	90 35	West Memphis	124 40	Redway
91 34	Dumas	91 35	Wynne	119 37	Reedley
93 33	El Dorado			118 36	Ridgecrest
91 33	Eudora	CALIFORNIA		117 34	Riverside
94 36	Fayetteville	116 35	Afton	121 39	Roseville
92 34	Fordyce	121 41	Alturas	121 39	Sacramento
91 35	Forrest City	119 35	Bakersfield	121 38	San Andreas
94 35	Fort Smith	117 35	Barstow	118 33	San Clemente
92 34	Hampton	120 38	Bear Valley	117 33	San Diego
93 36	Harrison	117 37	Beatty Junction	122 38	San Francisco
92 35	Heber Springs	118 38	Benton	122 37	San Jose
94 34	Hope	118 37	Bishop	121 35	San Luis Obispo
93 35	Hot Springs	114 34	Black Meadow Landing	122 38	San Mateo
91 36	Hoxie	115 34	Blythe	123 38	San Rafael
94 36	Huntsville	120 41	Brockman	120 34	Santa Barbara
93 36	Jasper	115 36	Calada	121 37	Santa Clara
91 36	Jonesboro	115 33	Calexico	122 37	Santa Cruz
92 35	Little Rock	122 36	Carmel Valley	120 35	Santa Maria
93 33	Magnolia	120 42	Cedarville	123 38	Santa Rosa
93 34	Malvern	122 40	Chico	117 36	Searles Valley
92 36	Mammoth Spring	122 39	Colusa	120 38	Sonora
91 35	Marianna	122 38	Concord	120 39	South Lake Tahoe
93 36	Marshall	123 40	Covelo	121 38	Stockton
92 36	Melbourne	124 42	Crescent City	121 40	Susanville
94 35	Mena	122 39	Davis	121 42	Tulelake
92 34	Monticello	116 36	Death Valley Junction	123 39	Ukiah
93 35	Morrilton	122 42	Dorris	122 38	Vallejo
94 35	Mount Ida	116 33	El Centro	119 36	Visalia
92 36	Mountain View	121 36	El Paso de Robles	123 41	Weaverville
94 34	Murfreesboro	124 41	Eureka	122 40	Willows
94 34	Nashville	124 39	Fort Bragg	123 42	Yreka
94 35	Ozark	120 37	Fresno	122 39	Yuba City
91 36	Paragould	121 39	Grass Valley		
94 35	Paris	120 36	Hanford	COLORADO	
93 35	Perryville	121 37	Hollister	106 37	Alamosa
90 36	Piggott	116 34	Indio	107 39	Aspen
92 34	Pine Bluff	121 38	Ione	105 40	Aurora
91 36	Pocahontas	123 39	Lakeport	105 40	Boulder
93 34	Prescott	118 35	Lancaster	109 41	Bower Place
92 34	Rison	122 39	Linda	104 37	Branson
93 35	Russellville	118 34	Los Angeles	102 39	Burlington
92 35	Searcy	120 40	Loyalton	105 38	Canon City
92 34	Sheridan	120 37	Madera	105 39	Castle Rock
95 36	Siloam Springs	119 38	Mammoth Lakes	106 38	Center
93 33	Stamps	120 37	Mariposa	106 40	Central City
92 34	Star City	120 37	Merced	102 39	Cheyenne Wells
92 35	Stuttgart	121 38	Modesto	108 39	Clifton
94 33	Texarkana	122 38	Napa	105 39	Colorado Springs
91 36	Trumann	115 35	Needles	107 41	Columbine
91 36	Tuckerman	122 38	Oakland	109 37	Cortez
94 35	Van Buren	119 34	Oxnard	108 41	Craig
94 35	Waldron	120 40	Portola	107 38	Creede
92 34	Warren	122 40	Red Bluff	108 39	Delta

105 40	Denver	102 40	Wray	82 30	Hastings
108 37	Durango	103 40	Yuma	83 28	Holiday
103 38	Eads			80 25	Homestead
105 39	Elizabeth	CONNECTICUT		81 26	Immokalee
105 40	Englewood	74 42	Amenia Union	82 30	Jacksonville
106 40	Estes Park	73 41	Bridgeport	81 30	Jacksonville Beach
106 39	Fairplay	73 42	Hartford	83 31	Jasper
105 41	Fort Collins	73 42	Middletown	82 25	Key West
104 40	Fort Morgan	73 41	New Haven	81 28	Kissimmee
106 40	Frisco	72 41	New London	82 30	Lake Butler
103 38	Gilpin	72 42	Norwich	83 30	Lake City
109 39	Grand Junction	74 41	Stamford	82 29	Leesburg
104 41	Grover	72 42	Storrs	82 30	Macclenny
107 39	Gunnison	72 42	Willimantic	83 30	Madison
102 38	Holly			81 25	Marathon
102 41	Holyoke	DELAWARE		85 31	Marianna
106 38	Hooper	76 40	Wilmington	83 30	Mayo
103 39	Hugo	76 39	Dover	81 28	Melbourne
105 40	Idaho Springs	75 40	Claymont	80 26	Miami
102 41	Julesburg	75 39	Milford	87 31	Milton
106 40	Kremmling	75 38	Selbyville	84 31	Monticello
104 38	La Junta	76 38	Delmar	82 26	Naples
107 38	Lake City			82 29	Ocala
105 40	Lakewood	DISTRICT OF COLUMBIA		81 27	Okeechobee
103 38	Lamar	77 39	Washington	82 30	Orange Park
103 38	Las Animas			81 29	Orlando
106 39	Leadville	FLORIDA		82 30	Palatka
104 39	Limon	85 30	Apalachicola	86 30	Panama City
105 38	Lombard Village	82 27	Arcadia	87 30	Pensacola
108 39	Maher	81 27	Belle Glade	84 30	Perry
106 37	Manassa	85 30	Blountstown	82 27	Port Charlotte
106 38	Monte Vista	86 31	Bonifay	85 31	Quincy
108 38	Montrose	83 27	Bradenton	81 29	Sanford
109 38	Nucla	83 30	Branford	83 27	Sarasota
104 38	Ordway	85 30	Bristol	81 27	Sebring
108 38	Ouray	82 29	Brooksville	82 30	Starke
107 37	Pagosa Springs	83 28	Clearwater	80 27	Stuart
105 38	Pueblo	81 27	Clewiston	84 30	Tallahassee
109 40	Rangely	84 30	Crawfordville	82 28	Tampa
108 40	Rifle	83 30	Cross City	83 30	Trenton
106 39	Salida	86 30	Crystal Lake	80 28	Vero Beach
105 37	San Luis	83 29	Crystal River	81 27	Washington Park
108 38	Silverton	81 29	Daytona Beach	82 28	Wauchula
103 37	Springfield	86 31	De Funiak Springs	80 27	West Palm Beach
107 40	Steamboat Springs	88 31	Enon	85 30	Wewahitchka
103 41	Sterling	81 31	Fernandina Beach	82 29	Wildwood
108 38	Telluride	87 31	Ferry Pass	82 29	Williston
105 37	Trinidad	81 29	Flagler Beach	82 28	Winter Haven
106 40	Vail	83 25	Fort Jefferson	82 31	Yulee
106 41	Walden	80 26	Fort Lauderdale		
105 38	Walsenburg	82 27	Fort Myers		
102 37	Walsh	80 27	Fort Pierce		
105 38	Westcliffe	87 30	Fort Walton Beach		
105 39	Woodland Park	82 30	Gainesville		

GEORGIA

83 31	Adel	84 35	Dahlonega	82 32	Metter
83 32	Ailey	85 34	Dallas	83 33	Milledgeville
83 32	Alamo	85 35	Dalton	82 33	Millen
84 32	Albany	81 31	Darien	85 33	Molena
83 31	Alexis	84 32	Dawson	84 34	Monroe
85 33	Allendale	84 34	Dawsonville	84 32	Montezuma
82 32	Alma	83 32	Denton	84 33	Monticello
84 32	Americus	85 31	Donalsonville	84 31	Moultrie
84 32	Andersonville	83 32	Douglas	82 31	Nahunta
85 31	Arlington	83 33	Dublin	83 31	Nashville
84 32	Ashburn	84 35	East Ellijay	85 33	Newnan
83 34	Athens	83 32	Eastman	84 31	Newton
84 34	Atlanta	83 33	Eatonton	84 34	North Atlanta
82 33	Augusta	83 34	Elberton	83 32	Ocilla
85 31	Bainbridge	84 32	Ellaville	85 33	Peachtree City
84 33	Barnesville	83 32	Fitzgerald	83 31	Pearson
82 32	Baxley	84 34	Forest Park	82 32	Pembroke
82 31	Blackshear	84 33	Forsyth	85 32	Preston
84 35	Blairsville	85 32	Fort Gaines	84 31	Quitman
85 31	Blakely	84 33	Fort Valley	85 32	Richland
83 33	Blountsville	85 33	Franklin	84 33	Roberta
84 35	Blue Ridge	84 34	Gainesville	83 32	Rochelle
84 31	Boston	83 33	Gibson	85 34	Rome
85 34	Bremen	82 32	Glennville	83 33	Sandersville
81 31	Brunswick	83 33	Gordon	81 32	Savannah
85 32	Buena Vista	83 34	Greensboro	83 32	Soperton
84 33	Butler	84 33	Griffin	83 33	Sparta
84 31	Cairo	83 34	Hartwell	82 32	Statesboro
85 35	Calhoun	83 32	Hawkinsville	82 30	Stokesville
84 31	Camilla	82 32	Hinesville	85 34	Summerville
84 34	Canton	83 34	Homer	84 35	Sunnyside
85 34	Cartersville	83 31	Homerville	82 33	Swainsboro
81 33	Cedar Bluff Landing	84 33	Jackson	82 33	Sylvania
85 34	Cedartown	84 34	Jasper	84 32	Sylvester
85 35	Chatsworth	83 33	Jeffersonville	85 33	Talbotton
82 32	Claxton	82 32	Jesup	84 33	Thomaston
83 35	Clayton	82 31	Kingsland	83 33	Thomson
84 35	Cleveland	85 35	La Fayette	84 31	Tifton
83 32	Cochran	85 33	La Grange	83 35	Toccoa
85 31	Colquitt	83 31	Lakeland	86 35	Trenton
85 32	Columbus	83 34	Lavonia	83 31	Valdosta
83 34	Comer	84 34	Lawrenceville	82 32	Vidalia
83 34	Commerce	84 32	Leesburg	84 32	Vienna
84 34	Conyers	82 34	Lincolnton	85 34	Villa Rica
84 32	Cordele	85 34	Lithia Springs	84 33	Warner Robins
84 35	Cornelia	82 33	Louisville	83 33	Warrenton
84 34	Covington	82 32	Ludowici	83 34	Washington
83 34	Crawford	85 34	Mableton	83 34	Watkinsville
83 34	Crawfordville	84 33	Macon	85 33	Waverly Hall
85 32	Crossroads	83 34	Madison	82 31	Waycross
84 34	Cumming	85 33	Manchester	82 33	Waynesboro
85 32	Cusseta	82 34	Martinez	85 35	Westside
85 32	Cuthbert	84 33	McDonough	84 34	Winder
		83 32	McRae	83 33	Wrightsville

HAWAII

156 19 Captain Cook
155 20 Hilo
156 20 Holualoa
158 21 Honolulu
156 21 Kahului
159 22 Kapaa
160 22 Kekaha
155 19 Pahala
158 22 Wahiawa
157 21 Wailuku

IDAHO

115 45 Abstein Place
113 43 American Falls
113 44 Arco
111 44 Ashton
117 45 Bear
116 42 Bengoechea Place
112 43 Blackfoot
116 49 Bonners Ferry
115 47 Cayuse Junction
117 48 Coeur d'Alene
117 42 Crutcher Crossing
111 44 Driggs
112 44 Dubois
115 46 Elk City
116 41 Elkhorn
116 44 Emmett
115 43 Fairfield
114 46 Gibbonsville
115 43 Gooding
115 42 Hollister
116 44 Horseshoe Bend
111 43 Irwin
115 43 Jerome
116 46 Kamiah
116 48 Kellogg
114 44 Ketchum
111 45 Lake
117 49 Lamb Creek
113 45 Leadore
117 46 Lewiston
112 42 Malad City
113 42 Malta
116 45 McCall
117 43 Melba
116 44 Meridian
111 42 Montpelier
117 47 Moscow
116 43 Mountain Home
117 44 Nampa
114 42 Oakley
116 46 Orofino

117 44 Payette
117 47 Plummer
112 43 Pocatello
112 42 Preston
112 44 Rexburg
112 44 Rigby
114 43 Rupert
114 45 Salmon
114 43 Shoshone
112 43 Soda Springs
115 44 Stanley
114 43 Twin Falls
116 47 Wallace
117 44 Weiser

ILLINOIS

91 41 Aledo
89 37 Anna
90 43 Apple River
90 40 Athens
88 42 Aurora
90 40 Beardstown
90 39 Belleville
89 42 Belvidere
90 39 Breese
89 37 Cairo
90 41 Canton
89 38 Carbondale
90 39 Carlinville
88 38 Carmi
89 39 Centralia
88 40 Champaign
88 39 Charleston
90 38 Chester
88 42 Chicago
89 40 Clinton
88 42 Crystal Lake
88 40 Danville
89 42 De Kalb
89 40 Decatur
89 42 Dixon
88 41 Dwight
89 39 Effingham
88 42 Elmhurst
89 41 Eureka
88 39 Flora
90 42 Freeport
90 41 Galesburg
88 37 Golconda
90 39 Granite City
89 41 Granville
88 38 Grayville
89 39 Greenville
91 40 Hamilton

91 39 Hardin
89 38 Harrisburg
90 40 Havana
89 41 Henry
89 39 Hillsboro
90 40 Jacksonville
90 39 Jerseyville
88 42 Joliet
88 41 Kankakee
90 41 Kewanee
88 39 Lawrenceville
89 40 Lincoln
91 40 Macomb
89 38 Marion
88 39 Marshall
89 38 McLeansboro
89 37 Metropolis
92 40 Meyer
91 41 Monmouth
89 40 Monticello
88 41 Morris
89 37 Mounds
88 38 Mount Carmel
91 40 Mount Sterling
89 38 Mount Vernon
89 38 Nashville
88 39 Neoga
88 39 Newton
89 41 Normal
88 39 Olney
91 41 Oquawka
89 41 Ottawa
88 40 Paris
88 40 Paxton
90 41 Pekin
90 41 Peoria
89 38 Pinckneyville
91 40 Pittsfield
89 42 Plano
89 41 Princeton
90 41 Princeville
91 40 Quincy
88 39 Robinson
89 42 Rochelle
91 42 Rock Island
89 42 Rockford
88 37 Rosiclare
91 40 Rushville
90 42 Savanna
88 38 Shawneetown
89 39 Shelbyville
90 40 Springfield
90 42 Sterling
89 40 Sullivan

89 40 Taylorville
 88 40 Tuscola
 89 39 Vandalia
 89 37 Vienna
 90 38 Waterloo
 88 41 Watseka
 88 42 Waukegan
 89 38 Wayne City
 89 38 West Frankfort
 90 39 White Hall
 90 40 Winchester

INDIANA

88 40 Ambia
 86 40 Anderson
 85 42 Angola
 86 39 Annandale Estates
 87 40 Attica
 85 41 Auburn
 86 39 Austin
 86 41 Barbee
 85 39 Batesville
 86 39 Bedford
 85 41 Berne
 87 39 Bloomington
 85 41 Bluffton
 87 38 Boonville
 87 40 Brazil
 85 39 Brookville
 86 40 Brownsburg
 86 40 Carmel
 85 41 Columbia City
 86 39 Columbus
 85 40 Connersville
 86 38 Corydon
 87 40 Crawfordsville
 87 41 Delphi
 88 41 Dyer
 86 42 Elkhart
 88 38 Evansville
 87 40 Fairview Park
 87 39 Farmersburg
 85 41 Fort Wayne
 87 40 Frankfort
 87 42 Gary
 86 40 Gas City
 87 40 Greencastle
 86 40 Greenfield
 85 39 Greensburg
 88 42 Hammond
 85 40 Hartford City
 85 41 Huntington
 86 40 Indianapolis
 87 38 Jasper

85 41 Kendallville
 87 41 Kentland
 86 41 Kewanna
 86 40 Kokomo
 87 40 Lafayette
 85 42 Lagrange
 85 39 Lawrenceburg
 86 40 Lebanon
 85 40 Liberty
 87 39 Linton
 86 41 Logansport
 87 39 Loogootee
 85 39 Madison
 86 39 Martinsville
 87 41 Merrillville
 87 42 Michigan City
 87 41 Monticello
 85 40 Muncie
 86 38 New Albany
 85 40 New Castle
 86 39 New Pekin
 86 40 New Whiteland
 87 41 North Judson
 86 39 North Vernon
 86 38 Oak Park
 86 39 Paoli
 86 41 Peru
 87 38 Petersburg
 86 41 Plymouth
 87 42 Portage
 85 40 Portland
 88 38 Poseyville
 88 38 Princeton
 87 41 Rensselaer
 85 40 Richmond
 85 39 Rising Sun
 86 41 Rochester
 87 38 Rockport
 87 40 Rockville
 85 40 Rushville
 86 39 Seymour
 86 40 Shelbyville
 86 42 South Bend
 87 39 Spencer
 87 39 Sullivan
 87 38 Tell City
 87 39 Terre Haute
 86 40 Tipton
 85 39 Vevay
 88 39 Vincennes
 86 41 Wabash
 86 41 Warsaw
 87 39 Washington
 87 40 Williamsport

87 41 Winamac
 85 40 Winchester

IOWA

97 43 Akron
 93 41 Albia
 94 43 Algona
 93 42 Altoona
 94 42 Ames
 91 42 Anamosa
 95 41 Atlantic
 95 42 Audubon
 95 41 Bedford
 92 41 Bloomfield
 94 42 Boone
 91 41 Burlington
 95 42 Carroll
 92 43 Cedar Falls
 92 42 Cedar Rapids
 93 41 Chariton
 93 43 Charles City
 96 43 Cherokee
 90 42 Clinton
 95 41 Corning
 96 41 Council Bluffs
 92 43 Cresco
 94 41 Creston
 91 42 Davenport
 92 43 Decorah
 95 42 Denison
 94 42 Des Moines
 91 43 Dubuque
 94 43 Eagle Grove
 95 43 Emmetsburg
 95 43 Estherville
 92 41 Fairfield
 94 43 Forest City
 94 42 Fort Dodge
 94 43 Garner
 97 41 Genoa
 96 41 Glenwood
 94 41 Greenfield
 93 42 Grinnell
 93 42 Grundy Center
 95 42 Guthrie Center
 91 43 Guttenberg
 96 41 Hamburg
 93 43 Hampton
 95 42 Harlan
 94 43 Humboldt
 95 42 Ida Grove
 92 42 Independence
 94 41 Indianola
 92 42 Iowa City

93 43	Iowa Falls	KANSAS	95 39	Lawrence	
94 42	Jefferson	97 39	Abilene	95 39	Leavenworth
91 40	Keokuk	96 39	Alma	101 38	Leoti
92 41	Keosauqua	98 37	Anthony	101 37	Liberal
95 42	Kimballton	97 37	Arkansas City	98 38	Lyons
94 41	Lamoni	100 37	Ashland	97 39	Manhattan
91 42	Manchester	95 40	Atchison	98 40	Mankato
91 42	Maquoketa	101 40	Atwood	102 38	Manter
92 42	Marengo	98 40	Belleville	97 40	Marysville
93 42	Marshalltown	98 39	Beloit	98 38	McPherson
93 43	Mason City	102 40	Bird City	100 37	Meade
96 42	Missouri Valley	96 38	Burlington	99 37	Medicine Lodge
93 41	Moulton	95 38	Chanute	98 39	Minneapolis
94 41	Mount Ayr	100 38	Cimarron	96 37	Neodesha
92 41	Mount Pleasant	96 37	Coffeyville	100 38	Ness City
92 43	New Hampton	101 39	Colby	97 38	Newton
93 42	Newton	99 37	Coldwater	100 40	Norton
93 43	Northwood	98 40	Concordia	101 39	Oakley
92 43	Oelwein	97 38	Cottonwood Falls	101 40	Oberlin
96 42	Onawa	96 39	Council Grove	96 39	Osage City
96 43	Orange City	100 38	Dighton	99 39	Osborne
93 43	Osage	100 38	Dodge City	95 39	Overland Park
94 41	Osceola	95 39	Dunavant	95 39	Paola
93 41	Oskaloosa	97 38	El Dorado	95 37	Parsons
92 41	Ottumwa	102 37	Elkhart	99 40	Phillipsburg
93 43	Parkersburg	98 39	Ellsworth	95 37	Pittsburg
93 41	Pella	96 38	Emporia	99 39	Plainville
94 42	Perry	96 38	Eureka	95 38	Pleasanton
95 43	Pocahontas	95 38	Fort Scott	99 38	Pratt
95 41	Red Oak	95 37	Galena	100 39	Quinter
96 43	Rock Rapids	101 38	Garden City	94 38	Richmond
95 42	Rockwell City	95 38	Garnett	99 39	Russell
95 42	Sac City	102 39	Goodland	98 38	Saint Paul
96 43	Sheldon	99 38	Great Bend	98 39	Salina
95 41	Shenandoah	99 38	Greensburg	101 38	Scott City
96 43	Sibley	99 39	Hays	96 37	Sedan
92 41	Sigourney	96 40	Hiawatha	101 40	Selden
96 43	Sioux City	100 39	Hill City	96 40	Seneca
95 43	Spencer	97 38	Hillsboro	102 39	Sharon Springs
95 43	Spirit Lake	96 39	Holton	99 40	Smith Center
95 43	Storm Lake	96 37	Howard	99 38	Stafford
93 42	Tama	101 37	Hugoton	101 37	Sublette
91 42	Tipton	98 38	Hutchinson	98 39	Sylvan Grove
92 40	Vincennes	95 38	Iola	102 38	Syracuse
92 42	Vinton	100 38	Jetmore	96 39	Topeka
92 41	Washington	97 39	Junction City	101 38	Ulysses
91 43	Waukon	103 38	Kanco	95 39	Valley Falls
92 43	Waverly	95 39	Kansas City	100 39	Wa Keeney
94 42	Webster City	98 38	Kingman	97 39	Wakefield
91 42	West Liberty	99 38	Kinsley	96 39	Wamego
94 41	Winterset	99 39	La Crosse	97 40	Washington
		101 38	Lakin	95 40	Wathena
		96 38	Landergin	97 37	Wellington
		99 38	Larned	97 38	Wichita

96 38	Yates Center	85 37	Greensburg	88 37	Smithland
		86 38	Hardinsburg	85 37	Somerset
KENTUCKY		85 38	Harrodsburg	82 38	South Williamson
85 37	Albany	83 37	Hazard	85 38	Springfield
83 37	Altro	88 38	Henderson	85 38	Stamping Ground
85 38	Anderson City.	86 37	Hillview	85 38	Stanford
85 37	Argyle	83 37	Hindman	84 38	Stanton
83 37	Asher	86 38	Hodgenville	86 37	Tompkinsville
83 38	Ashland	87 37	Hopkinsville	83 39	Vanceburg
84 38	Ashland Park	86 37	Horse Cave	85 38	Versailles
84 39	Augusta	84 38	Irvine	85 39	Warsaw
84 37	Barbourville	83 37	Jenkins	83 38	West Liberty
85 38	Bardstown	85 38	Junction City	84 37	Whitley City
85 37	Barrier	89 37	La Center	89 37	Wickliffe
84 38	Beattyville	85 38	La Grange	85 39	Williamstown
82 38	Beauty	85 38	Lancaster	84 38	Winchester
87 37	Beaver Dam	85 38	Lawrenceburg		
85 39	Bedford	85 38	Lebanon	LOUISIANA	
88 37	Benton	86 37	Leitchfield	92 31	Alexandria
84 37	Booneville	87 38	Lewisport	91 31	Alice
86 37	Bowling Green	87 37	Livermore	93 33	Arcadia
86 38	Brandenburg	84 37	London	91 31	Baker
84 37	Brodhead	83 38	Louisa	92 33	Bastrop
85 37	Burkesville	86 38	Louisville	91 30	Baton Rouge
88 37	Cadiz	87 37	Madisonville	90 31	Bogalusa
85 37	Campbellsville	84 37	Manchester	89 29	Boothville
84 38	Campton	88 37	Marion	94 33	Bossier City
84 38	Carlisle	89 37	Mayfield	92 30	Breaux Bridge
85 39	Carrollton	84 39	Maysville	92 31	Bunkie
87 37	Central City	84 37	McKee	93 30	Cameron
83 38	Clearfield	88 38	Morganfield	90 30	Chalmette
89 37	Clinton	87 37	Morgantown	91 29	Chauvin
85 37	Columbia	84 38	Mount Sterling	92 32	Clarks
84 37	Corbin	88 37	Murray	93 32	Colfax
85 39	Covington	84 39	Newport	93 32	Coushatta
83 37	Cumberland	85 38	Nicholasville	92 30	Crowley
84 38	Cynthiana	87 38	Owensboro	93 31	De Ridder
85 38	Danville	85 39	Owenton	91 30	Denham Springs
88 37	Eddyville	89 37	Paducah	91 30	Donaldsonville
86 37	Edmonton	83 38	Paintsville	91 33	Epps
86 38	Elizabethtown	84 38	Paris	92 33	Farmerville
82 37	Elkhorn City	84 37	Pineville	91 33	Forest
87 37	Elkton	83 38	Prestonsburg	90 29	Galliano
85 38	Eminence	88 37	Princeton	91 31	Greensburg
84 39	Falmouth	84 38	Richmond	90 31	Hammond
83 39	Flatwoods	85 37	Russell Springs	93 33	Homer
84 38	Flemingsburg	87 37	Russellville	91 31	Jackson
85 39	Florence	84 38	Salt Lick	92 32	Jena
85 38	Frankfort	83 38	Salyersville	93 30	Jennings
87 37	Franklin	83 38	Sandy Hook	93 32	Jonesboro
84 38	Frenchburg	86 37	Scottsville	92 32	Jonesville
89 37	Fulton	88 38	Sebree	92 30	Kaplan
86 37	Glasgow	85 38	Shelbyville	92 30	Lafayette
83 38	Grayson	86 38	Shepherdsville	93 30	Lake Charles

91 33	Lake Providence	69 44	Rockland	85 43	Alma
90 30	Laplace	71 45	Rumford	83 45	Alpena
93 31	Leesville	71 43	Sanford	84 42	Ann Arbor
91 30	Lutcher	67 46	Vanceboro	87 45	Arthur Bay
94 32	Mansfield	70 45	Waterville	83 44	Bad Axe
93 32	Many			86 44	Baldwin
94 31	Merryville		MARYLAND	85 42	Battle Creek
90 30	Metairie	77 39	Baltimore	84 44	Bay City
93 33	Minden	78 39	Brunswick	85 44	Big Rapids
92 33	Monroe	77 38	California	84 45	Biggs Settlement
91 30	Morgan City	76 39	Cambridge	85 45	Boyne City
93 32	Natchitoches	76 39	Centreville	84 47	Brassar
92 30	New Iberia	76 39	Chestertown	84 43	Burton
90 30	New Orleans	77 39	Columbia	85 44	Cadillac
91 31	New Roads	76 38	Crisfield	83 43	Caro
91 32	Newellton	79 40	Cumberland	85 43	Charlotte
90 30	Norco	76 39	Easton	84 46	Cheboygan
93 31	Oakdale	76 40	Elkton	85 44	Clare
92 31	Opelousas	77 40	Emmitsburg	85 42	Coldwater
91 30	Pierre Part	76 39	Essex	86 47	Deer Park
91 30	Plaquemine	76 39	Federalsburg	83 42	Detroit
91 30	Port Allen	77 39	Glen Burnie	86 42	Dowagiac
92 32	Rayville	78 40	Hagerstown	83 44	East Tawas
91 30	Rhodes	78 40	Halfway	85 45	Elk Rapids
93 33	Ruston	76 40	Havre De Grace	85 47	Emerson
94 33	Shreveport	75 38	Ocean City	87 46	Escanaba
90 30	Slidell	77 39	Oxon Hill	84 43	Flint
91 32	Tallulah	77 39	Prince Frederick	86 45	Frankfort
91 32	Vidalia	76 38	Salisbury	86 43	Fremont
92 31	Ville Platte	77 39	Silver Spring	85 45	Gaylord
94 30	Vinton	77 39	Waldorf	84 44	Gladwin
93 32	Winnfield	79 39	Westernport	85 45	Grayling
92 32	Winnsboro	77 40	Westminster	85 43	Greenville
				83 45	Harrisville
				84 45	Hillman
MAINE		MASSACHUSETTS		85 42	Hillsdale
70 46	Attean	71 42	Boston	86 43	Holland
69 45	Bangor	71 42	Brockton	89 47	Houghton
68 44	Bar Harbor	72 43	Fitchburg	85 44	Houghton Lake
70 44	Bath	73 43	Greenfield	84 43	Howell
69 44	Belfast	70 42	Hyannis	85 43	Ionia
70 43	Biddeford	71 43	Lowell	88 46	Iron Mountain
70 44	Boothbay Harbor	71 42	Lynn	89 46	Iron River
67 45	Calais	70 41	Nantucket	90 46	Ironwood
70 47	Clayton Lake	71 42	New Bedford	84 42	Jackson
69 45	Dover-Foxcroft	73 43	North Adams	86 42	Kalamazoo
68 45	Ellsworth	73 42	Northampton	85 45	Kalkaska
69 47	Fort Kent	71 42	Quincy	88 47	L'Anse
68 46	Houlton	73 42	Springfield	85 44	Lake City
71 46	Keough	71 41	Vineyard Haven	85 43	Lansing
70 44	Lewiston	72 42	Worcester	83 43	Lapeer
69 46	Millinocket			88 47	Laurium
71 44	Norway		MICHIGAN	87 44	Little Point Sable
70 44	Portland	84 42	Adrian	86 44	Ludington
68 47	Presque Isle	86 43	Allegan		

85 46	Mackinac Island	91 48	Clear Lake	95 46	Sauk Centre
85 46	Mackinaw City	93 45	Coon Rapids	94 46	Sauk Rapids
86 44	Manistee	93 45	Cottage Grove	94 45	Shakopee
86 46	Manistique	97 48	Crookston	91 47	Silver Bay
87 47	Marquette	96 47	Detroit Lakes	96 44	Slayton
88 45	Menominee	92 47	Duluth	92 44	Spring Valley
85 43	Middleville	96 46	Elbow Lake	95 46	Staples
84 44	Midland	92 48	Ely	96 48	Thief River Falls
83 42	Monroe	94 44	Fairmont	96 47	Twin Valley
87 46	Munising	93 44	Faribault	96 44	Tyler
86 43	Muskegon	96 46	Fergus Falls	93 48	Virginia
87 42	New Buffalo	92 45	Frontenac	95 46	Wadena
86 45	Northport	94 45	Gaylord	97 48	Warren
84 43	Ovid	95 46	Glenwood	95 49	Warroad
85 45	Petoskey	90 48	Grand Marais	94 44	Waseca
83 43	Pontiac	94 47	Grand Rapids	96 46	Wheaton
82 43	Port Huron	96 45	Granite Falls	95 45	Willmar
86 44	Reed City	97 49	Hallock	95 44	Windom
88 48	Rock Harbor Lodge	92 46	Holyoke	92 44	Winona
84 45	Rogers City	94 45	Hutchinson	96 44	Worthington
84 43	Saginaw	93 49	International Falls		
83 43	Sandusky	95 44	Jackson	MISSISSIPPI	
85 44	Shepherd	93 44	Kasson	90 35	Abbeville
86 42	South Haven	92 44	Lake City	89 33	Ackerman
84 44	Standish	93 45	Lindstrom	88 34	Amory
83 43	Sterling Heights	95 45	Litchfield	90 34	Batesville
85 42	Sturgis	94 46	Little Falls	89 32	Bay Springs
86 45	Traverse City	94 48	Littlefork	89 31	Beatrice
84 44	West Branch	96 44	Luverne	89 31	Beaumont
90 47	White Pine	94 44	Madelia	90 33	Belzoni
89 48	Windigo	96 45	Madison	89 30	Biloxi
86 43	Wyoming	96 47	Mahnomen	89 35	Booneville
		94 44	Mankato	90 32	Brandon
		96 44	Marshall	90 32	Brookhaven
MINNESOTA		93 45	Minneapolis	89 34	Bruce
94 47	Aitkin	94 45	Minnetonka	91 31	Bude
93 44	Albert Lea	96 45	Montevideo	90 35	Byhalia
95 46	Alexandria	97 47	Moorhead	90 33	Canton
93 44	Austin	93 46	Mora	91 31	Centreville
95 48	Bagley	96 46	Morris	90 34	Charleston
95 49	Baudette	94 45	New Prague	91 34	Clarksdale
95 47	Bemidji	94 44	New Ulm	90 32	Collins
96 45	Benson	94 44	North Mankato	90 31	Columbia
94 49	Birchdale	95 45	Olivia	88 33	Columbus
94 44	Blue Earth	93 44	Owatonna	90 32	Crystal Springs
97 45	Bonanza Grove	95 47	Park Rapids	89 33	De Kalb
94 46	Brainerd	93 46	Pine City	90 33	Durant
97 46	Breckenridge	96 44	Pipestone	89 34	Eupora
94 45	Buffalo	94 46	Princeton	91 32	Fayette
93 45	Burnsville	96 48	Red Lake Falls	89 32	Forest
91 44	Caledonia	95 45	Redwood Falls	88 34	Fulton
93 46	Cambridge	92 44	Rochester	90 30	Gainesville
95 47	Cass Lake	96 49	Roseau	91 31	Gloster
94 45	Chaska	93 45	Roseville	91 33	Greenville
93 47	Chisholm				

90 34	Grenada	94 38	Appleton City	94 37	Lamar
89 31	Hattiesburg	90 38	Arnold	93 41	Lancaster
88 30	Helena	94 37	Aurora	93 38	Lebanon
90 35	Hernando	93 37	Ava	94 39	Lexington
89 35	Hickory Flat	91 39	Ballwin	92 38	Linn
89 34	Houston	92 38	Belle	91 39	Louisiana
88 32	Hurricane Creek	93 36	Blue Eye	90 37	Lutesville
91 33	Indianola	93 38	Bolivar	92 40	Macon
90 33	Itta Bena	93 39	Boonville	93 39	Marshall
88 35	Iuka	93 37	Branson	93 37	Marshfield
90 32	Jackson	93 40	Brookfield	94 40	Maysville
91 35	Jeffries	93 38	Buffalo	92 40	Memphis
92 31	Kienstra	94 38	Butler	94 41	Mercer
90 33	Kosciusko	93 39	California	92 39	Mexico
89 32	Laurel	93 38	Camdenton	93 40	Milan
90 33	Lena	92 40	Canton	92 39	Moberly
89 33	Louisville	90 37	Cape Girardeau	94 37	Monett
89 31	Lucedale	93 39	Carrollton	92 40	Monroe City
89 33	Macon	94 37	Carthage	92 39	Montgomery City
90 32	Magee	90 36	Caruthersville	95 40	Mound City
90 34	Marks	94 36	Caverna	92 37	Mountain Grove
91 33	Mayersville	89 37	Charleston	94 37	Neosho
90 31	McComb	94 40	Chillicothe	94 38	Nevada
89 32	Meridian	92 39	Columbia	91 39	O'Fallon
90 32	Monticello	92 36	Cornertown	93 37	Ozark
91 34	Mound Bayou	91 38	Cuba	92 39	Paris
89 34	New Albany	91 36	Current View	90 38	Perryville
89 32	Newton	90 37	Dexter	91 37	Piedmont
89 33	Philadelphia	95 38	Drexel	95 39	Platte City
90 31	Picayune	92 40	Edina	94 40	Plattsburg
89 34	Pontotoc	93 38	Eldon	90 37	Poplar Bluff
91 32	Port Gibson	91 37	Ellington	90 36	Portageville
90 32	Prentiss	90 38	Farmington	91 38	Potosi
89 31	Purvis	93 39	Fayette	94 39	Richmond
90 32	Raleigh	91 38	Flat River	94 40	Ridgeway
89 35	Rienzi	90 38	Fredericktown	92 38	Rolla
89 35	Ripley	92 39	Fulton	95 40	Saint Joseph
91 33	Rolling Fork	92 37	Gainesville	92 38	Salem
90 35	Senatobia	94 40	Gallatin	93 39	Salisbury
89 33	Starkville	95 39	Gladstone	95 40	Savannah
88 31	State Line	94 40	Grant City	93 39	Sedalia
90 35	Tunica	94 37	Greenfield	92 40	Shelbina
89 34	Tupelo	94 40	Hamilton	90 37	Sikeston
90 31	Tylertown	91 40	Hannibal	93 37	Springfield
90 33	Vaiden	91 39	Hermann	90 39	St. Louis
91 32	Vicksburg	95 41	Hopkins	95 40	Stanberry
90 34	Water Valley	92 37	Houston	94 38	Stockton
89 32	Waynesboro	94 39	Independence	92 37	Thayer
89 34	West Point	91 38	Ironton	94 40	Trenton
90 33	Winona	92 39	Jefferson City	91 39	Troy
90 33	Yazoo City	95 37	Joplin	91 38	Union
		95 39	Kansas City	93 40	Unionville
		90 36	Kennett	91 37	Van Buren
		93 40	Kirksville	93 38	Versailles
MISSOURI					
92 41	Anson				

94 39 Warrensburg
93 38 Warsaw
91 39 Washington
96 40 Watson
92 38 Waynesville
94 38 Weaubleau
92 37 West Plains
94 39 Windsor
91 37 Winona

MONTANA

104 45 Albion
110 45 Alpine
113 46 Anaconda
114 49 Apgar
104 46 Baker
110 48 Big Sandy
110 46 Big Timber
109 46 Billings
107 49 Bone Crossing
116 47 Borax
112 46 Boulder
111 46 Bozeman
105 45 Broadus
113 49 Browning
113 46 Butte
111 49 Chester
109 49 Chinook
113 48 Choteau
106 47 Circle
109 46 Columbus
112 48 Conrad
112 49 Cut Bank
113 46 Deer Lodge
113 45 Dillon
113 47 Drummond
105 46 Ekalaka
112 45 Ennis
115 49 Eureka
107 46 Forsyth
108 45 Fort Smith
107 48 Glasgow
105 47 Glendive
111 48 Great Falls
114 46 Hamilton
108 46 Hardin
110 46 Harlowton
110 49 Havre
112 47 Helena
107 46 Hysham
107 47 Jordan
114 48 Kalispell
109 47 Lewistown
116 48 Libby

111 46 Livingston
107 45 Lodge Grass
108 48 Malta
108 47 Melstone
106 46 Miles City
114 47 Missoula
106 49 Opheim
115 47 Plains
105 49 Plentywood
114 48 Polson
105 48 Poplar
106 45 Quietus
109 48 Rattlesnake
109 45 Red Lodge
109 46 Ryegate
105 49 Scobey
112 49 Shelby
104 48 Sidney
110 47 Stanford
116 49 Sylvanite
105 47 Terry
115 48 Thompson Falls
112 46 Townsend
108 49 Turner
111 45 West Yellowstone
104 49 Westby
111 47 White Sulphur Springs
104 47 Wibaux
108 47 Winnett
106 48 Wolf Point

NEBRASKA

100 43 Ainsworth
98 42 Albion
99 40 Alma
100 42 Anselmo
102 42 Arthur
99 43 Atkinson
96 40 Auburn
98 41 Aurora
99 42 Bartlett
100 43 Bassett
97 40 Beatrice
96 41 Bellevue
102 40 Benkelman
96 42 Blair
98 43 Bloomfield
103 42 Bridgeport
99 42 Burwell
100 40 Cambridge
98 41 Central City
103 43 Chadron
102 41 Chappell
97 41 Columbus

101 41 Curtis
99 41 Dannebrog
97 41 David City
100 42 Dunning
100 41 Elwood
97 40 Fairbury
96 40 Falls City
101 42 Flats
99 40 Franklin
96 41 Fremont
98 41 Fullerton
98 41 Geneva
102 43 Gordon
98 41 Grand Island
102 41 Grant
104 43 Harrison
97 43 Hartington
98 41 Hastings
97 41 Havelock
101 41 Hayes Center
98 40 Hebron
103 42 Hemingford
99 40 Holdrege
97 40 Hubbell
102 42 Hyannis
102 41 Imperial
99 41 Kearney
104 41 Kimball
100 41 Lexington
97 41 Lincoln
99 41 Loup City
97 42 Madison
101 40 McCook
99 40 Minden
101 42 Mullen
96 41 Nebraska City
98 42 Neligh
101 41 North Platte
99 42 O'Neill
102 41 Ogallala
96 41 Omaha
99 42 Ord
102 41 Oshkosh
96 40 Pawnee City
97 42 Pender
98 42 Pierce
96 41 Plattsmouth
99 40 Red Cloud
103 42 Redington
95 40 Rulo
97 41 Schuyler
104 42 Scottsbluff
97 41 Seward
103 41 Sidney

96 42	South Sioux City	115 35	Laughlin	109 31	Antelope Wells
98 42	Spalding	118 40	Lovelock	104 33	Artesia
99 43	Spencer	118 42	McDermitt	103 37	Atencio
100 43	Springview	120 39	Minden	109 35	Black Rock
97 42	Stanton	114 37	Overton	108 34	Box Bar Place
101 41	Stapleton	120 40	Reno	104 32	Carlsbad
98 41	Stromsburg	119 41	Sulphur	106 34	Carrizozo
98 40	Superior	116 38	Tempiute	105 37	Cimarron
98 41	Sutton	114 40	Tippett	103 36	Clayton
99 42	Taylor	117 38	Tonopah	103 34	Clovis
96 40	Tecumseh	120 42	Vya	108 36	Crownpoint
96 42	Tekamah	115 41	Wells	108 32	Deming
101 42	Thedford	118 41	Winnemucca	107 37	Dulce
101 40	Trenton	119 39	Yerington	103 32	Eunice
101 43	Valentine			108 37	Farmington
97 41	Wahoo	NEW HAMPSHIRE		104 34	Fort Sumner
97 42	Wakefield	72 43	Claremont	105 32	Four Wells
97 42	Wayne	71 45	Colebrook	109 36	Gallup
97 42	West Point	72 43	Concord	108 35	Grants
97 40	Wilber	71 43	Dover	103 33	Hobbs
98 41	York	72 45	Groveton	107 36	Jemez Pueblo
		71 44	Laconia	107 32	Las Cruces
NEVADA		72 44	Lebanon	103 35	Logan
114 38	Acoma	71 43	Manchester	109 32	Lordsburg
117 39	Adits Mill	73 43	North Hinsdale	105 36	Los Alamos
116 40	Alpha	71 43	Portsmouth	105 34	Mesa
117 40	Amador	71 44	Wolfeboro	106 35	Moriarty
115 37	Arrowhead			103 34	Portales
114 39	Baker	NEW JERSEY		106 37	Questa
119 40	Bango	74 39	Atlantic City	104 37	Raton
117 41	Battle Mountain	75 40	Camden	109 34	Reserve
118 38	Blair	74 41	Elizabeth	105 33	Roswell
116 39	Bull Fork	75 41	Flemington	104 36	Roy
116 37	Cactus Springs	75 40	Glassboro	106 33	Ruidoso
115 38	Caliente	75 41	Hopatcong	106 35	San Felipe Pueblo
120 39	Carson City	74 41	Jersey City	106 36	Santa Fe
117 42	Cathcart	74 40	Lakewood	105 35	Santa Rosa
120 41	Cavin Place	74 40	Long Branch	109 37	Shiprock
116 42	Charleston	74 41	Madison	108 33	Silver City
116 36	Charleston Park	74 41	Newark	107 34	Socorro
119 42	Chinatown	74 41	North Plainfield	107 33	Truth Or Consequences
119 40	Clark	75 39	Ocean City	104 35	Tucumcari
114 41	Cliffside	74 41	Paterson	106 33	Tularosa
115 42	Contact	76 40	Pennsville	106 36	Upper Frijoles Crossing
115 40	Currie	75 41	Phillipsburg	109 33	Virden
119 38	Del Monte	74 40	Piscataway	105 36	Wagon Mound
116 41	Elko	74 41	Teaneck	106 32	White Sands
115 39	Ely	75 40	Trenton		
119 39	Fallon	75 39	Vineland	NEW YORK	
118 39	Gabbs	75 40	Willingboro	74 41	Adelphi
114 36	Gold Butte			74 43	Albany
117 37	Gold Point.	NEW MEXICO		74 43	Amsterdam
116 40	Jiggs	108 31	Alamo Hueco	74 41	Annadale
115 36	Las Vegas	107 35	Albuquerque	77 43	Auburn

73 42	Austerlitz	76 43	Syracuse	78 35	Hookerton	
78 43	Batavia	75 43	Utica	81 35	Kannapolis	
76 42	Binghamton	76 44	Watertown	80 36	King	
73 41	Brentwood	77 42	Watkins Glen	78 35	Kinston	
79 43	Buffalo	77 42	Waverly	79 35	Laurinburg	
74 42	Catskill	78 42	Wellsville	82 36	Lenoir	
75 41	Centereach	74 40	West Glens Falls	80 36	Lexington	
74 43	Cobleskill	80 42	Westfield	81 35	Lincolnton	
77 42	Corning	73 44	Whitehall	75 35	Little Kinnakeet	
76 43	Cortland	74 41	Yonkers	80 35	Locust	
71 41	East Hampton			78 34	Long View	
74 41	Eastchester	NORTH CAROLINA			78 36	Louisburg
77 42	Elmira	77 36	Ahoskie	79 35	Lumberton	
78 43	Geneseo	80 35	Albemarle	82 36	Marion	
77 43	Geneva	76 36	Alder Branch	83 36	Mars Hill	
74 43	Gloversville	82 37	Apple Grove	77 35	Maysville	
75 44	Gouverneur	80 36	Asheboro	79 37	Milton	
73 43	Hoosick Falls	83 36	Asheville	81 36	Mocksville	
75 43	Ilion	76 35	Atlantic	81 35	Monroe	
76 42	Ithaca	82 36	Bacchus	82 36	Morganton	
74 41	Jamaica	82 36	Banner Elk	84 35	Murphy	
79 42	Jamestown	77 35	Bayboro	81 36	Newton	
74 42	Kingston	77 36	Belhaven	81 36	North Wilkesboro	
74 42	Levittown	76 35	Beulah	79 36	Oxford	
76 44	Lowville	82 36	Boone	77 36	Plymouth	
74 41	Mahopac	83 35	Brevard	79 35	Raeford	
74 45	Malone	83 35	Bryson City	79 36	Raleigh	
78 43	Medina	78 35	Burgaw	78 36	Roanoke Rapids	
75 42	Monticello	79 36	Burlington	84 35	Robbinsville	
76 45	Morristown	79 36	Carrboro	80 35	Rockingham	
74 41	New City	80 37	Central Area	78 36	Rocky Mount	
74 41	New York	81 35	Charlotte	75 36	Rodanthe	
77 43	Newark	78 35	Clinton	79 36	Roxboro	
74 42	Newburgh	76 36	Columbia	80 36	Salisbury	
79 43	Niagara Falls	82 35	Columbus	79 35	Sanford	
76 43	Norwich	76 37	Corys	77 37	Severn	
75 45	Ogdensburg	79 35	Dunn	82 35	Shelby	
78 42	Olean	79 36	Durham	79 36	Siler City	
76 43	Oneida	77 36	Edenton	78 36	Smithfield	
75 42	Oneonta	76 36	Elizabeth City	79 35	Southern Pines	
77 43	Oswego	78 36	Elm City	78 34	Southport	
77 43	Penn Yan	79 35	Fayetteville	81 37	Sparta	
78 43	Perry	78 37	Gaston	82 36	Spruce Pine	
73 45	Plattsburgh	81 35	Gastonia	81 36	Statesville	
74 42	Poughkeepsie	77 36	Gatesville	83 35	Sylva	
78 43	Rochester	78 35	Goldsboro	78 36	Tarboro	
74 44	Saranac Lake	80 36	Greensboro	81 36	Taylorsville	
74 43	Saratoga Springs	77 36	Greenville	77 34	Thomas Landing	
74 43	Schenectady	77 35	Havelock	81 37	Toast	
77 43	Seneca Falls	84 35	Hayesville	80 35	Troy	
75 42	Sidney	78 36	Henderson	80 35	Wadesboro	
72 41	South Hampton	82 35	Hendersonville	78 36	Warrenton	
72 41	Southampton	76 36	Hertford	78 35	Warsaw	
74 43	Speculator	83 35	Highlands	83 35	Waynesville	

79 34	Whiteville	99 48	New Rockford	83 40	Lancaster
77 36	Williamston	98 48	Park River	82 40	Logan
78 34	Wilmington	104 46	Rhame	82 41	Lorain
77 36	Windsor	100 48	Rugby	83 41	Mansfield
80 36	Winston-Salem	102 48	Stanley	81 39	Marietta
81 36	Yadkinville	100 47	Steele	83 41	Marion
		98 47	Valley City	81 40	Martins Ferry
		101 48	Velva	82 39	McArthur
NORTH DAKOTA		97 46	Wahpeton	82 40	McConnelsville
99 46	Ashley	103 48	Watford City	81 42	Mentor
104 47	Beach	101 49	Westhope	82 39	Middleport
100 49	Belcourt	104 48	Williston	84 39	Milford
102 47	Beulah			82 41	Millersburg
101 47	Bismarck	OHIO		83 41	Mount Gilead
100 49	Bottineau	82 41	Akron	82 40	Mount Vernon
102 49	Bowbells	82 41	Ashland	84 41	Napoleon
103 46	Bowman	81 42	Ashtabula	85 40	New Paris
99 48	Cando	82 39	Athens	81 40	New Philadelphia
99 47	Carrington	84 40	Bellefontaine	82 40	Newark
101 47	Center	84 41	Bowling Green	83 41	Norwalk
98 47	Cooperstown	82 41	Brunswick	83 42	Oregon
103 49	Crosby	83 41	Bucyrus	84 41	Ottawa
99 48	Devils Lake	82 40	Byesville	85 40	Oxford
103 47	Dickinson	81 40	Cadiz	85 41	Paulding
97 49	Drayton	82 40	Caldwell	83 39	Piketon
102 46	Elgin	81 41	Canton	85 42	Pioneer
99 46	Ellendale	81 41	Carrollton	84 40	Piqua
103 47	Fairfield	85 41	Celina	83 40	Plain City
97 47	Fargo	81 42	Chardon	83 42	Port Clinton
98 48	Finley	82 38	Chesapeake	83 39	Portsmouth
101 46	Fort Yates	83 39	Chillicothe	83 40	Richwood
101 48	Garrison	84 39	Cincinnati	84 39	Ripley
97 48	Grand Forks	83 40	Circleville	83 41	Sandusky
104 49	Grenora	82 41	Cleveland	84 40	Sidney
98 46	Gwinner	83 40	Columbus	83 38	South Point
100 48	Harvey	82 40	Coshocton	84 40	Springfield
103 46	Hettinger	82 40	Crooksville	81 40	Steubenville
99 47	Jamestown	84 40	Dayton	83 41	Tiffin
102 49	Kenmare	84 41	Defiance	84 42	Toledo
103 47	Killdeer	83 40	Delaware	83 41	Upper Sandusky
98 46	La Moure	85 39	Delhi Hills	84 40	Urbana
98 48	Lakota	81 41	East Liverpool	85 41	Van Wert
98 49	Langdon	82 42	Euclid	84 41	Wapakoneta
99 48	Leeds	84 40	Fairborn	81 41	Warren
100 46	Linton	84 41	Findlay	84 42	Wauseon
98 46	Lisbon	84 41	Fort Shawnee	83 39	Wellston
101 47	Mandan	84 40	Franklin	84 39	West Union
104 46	Marmarth	83 41	Fremont	84 39	Wilmington
97 47	Mayville	82 39	Gallipolis	81 40	Woodsfield
100 47	McClusky	85 40	Greenville	82 41	Wooster
101 48	Minot	84 39	Hillsboro	81 41	Youngstown
102 49	Mohall	84 40	Jamestown	82 40	Zanesville
102 46	Mott	81 41	Kent		
99 49	Munich	84 41	Kenton		
100 47	Napoleon				

OKLAHOMA			96 37 Pawhuska	123 42 Grants Pass
97 35	Ada	97 36 Perry	122 45 Gresham	
99 35	Altus	94 35 Pocola	122 46 Gresham	
99 37	Alva	97 37 Ponca City	120 45 Heppner	
98 35	Anadarko	95 35 Poteau	122 46 Hood River	
96 34	Antlers	97 35 Purcell	117 43 Jordan Valley	
97 34	Ardmore	95 35 Sallisaw	118 45 La Grande	
96 34	Atoka	96 36 Sapulpa	123 45 Lake Oswego	
96 37	Bartlesville	99 36 Seiling	120 42 Lakeview	
101 37	Beaver	97 35 Seminole	121 45 Madras	
103 37	Boise City	100 36 Shattuck	121 42 Malin	
99 35	Burns Flat	97 35 Shawnee	123 45 McMinnville	
96 35	Checotah	95 35 Stigler	123 42 Medford	
98 37	Cherokee	97 36 Stillwater	118 46 Milton	
100 36	Cheyenne	95 36 Stilwell	124 45 Newport	
98 35	Chickasha	97 36 Stroud	122 44 Oakridge	
95 36	Chouteau	97 35 Sulphur	117 44 Ontario	
96 36	Claremore	95 36 Tahlequah	121 43 Paisley	
96 36	Cleveland	97 34 Tishomingo	119 46 Pendleton	
96 35	Coalgate	96 36 Tulsa	119 45 Pilot Rock	
98 35	Duncan	95 37 Vinita	123 46 Portland	
96 34	Durant	95 36 Wagoner	121 44 Prineville	
94 34	Eastport	98 34 Walters	124 44 Reedsport	
100 34	Eldorado	98 36 Watonga	123 43 Roseburg	
99 35	Elk City	98 34 Waurika	123 45 Salem	
98 36	Enid	99 36 Weatherford	123 46 St. Helens	
98 36	Fairview	95 35 Wilburton	124 45 Tillamook	
99 34	Frederick	99 36 Woodward	118 44 Unity	
102 37	Goodwell	98 36 Yukon	120 43 Wagon tire	
95 37	Grove		121 46 Wasco	
97 36	Guthrie	OREGON		
101 37	Guyton	123 45 Albany	PENNSYLVANIA	
101 36	Hitchland	122 42 Altamont	80 41 Aliquippa	
99 35	Hobart	119 42 Andrews	75 41 Allentown	
96 35	Holdenville	124 46 Astoria	78 41 Altoona	
100 35	Hollis	119 43 Frenchglen	79 40 Bedford	
96 34	Hugo	117 46 Bartlett	76 41 Berwick	
95 34	Idabel	118 42 Basque	75 41 Bethlehem	
98 36	Kingfisher	123 45 Beaverton	79 42 Bradford	
100 37	Laverne	121 44 Bend	80 41 Butler	
98 35	Lawton	120 46 Boardman	76 42 Carbondale	
97 34	Madill	124 42 Brookings	77 40 Carlisle	
100 35	Mangum	119 44 Burns	78 40 Chambersburg	
97 34	Marietta	122 43 Chiloquin	79 41 Clarion	
96 35	McAlester	121 46 City of The Dalles	78 42 Coudersport	
98 37	Medford	120 45 Condon	77 41 Danville	
95 37	Miami	124 43 Coos Bay	79 41 Du Bois	
95 36	Muskogee	123 45 Corvallis	76 42 Dushore	
97 35	Norman	123 45 Dallas	75 41 East Stroudsburg	
96 37	Nowata	120 44 Dayville	78 42 Emporium	
96 35	Okemah	118 43 Dunnean	80 42 Erie	
98 35	Oklahoma City	117 45 Enterprise	75 42 Forest City	
96 36	Okmulgee	123 44 Eugene	77 40 Gettysburg	
97 35	Pauls Valley	120 45 Fossil	77 40 Harrisburg	

75 42	Honesdale				
78 40	Huntingdon				
79 41	Indiana				
80 40	Jefferson				
79 40	Johnstown				
80 41	Kittanning				
76 40	Lancaster				
76 40	Lebanon				
76 41	Lehighton				
77 41	Lewisburg				
78 41	Lewistown				
77 41	Lock Haven				
77 42	Mansfield				
77 40	Marysville				
75 41	Matamoras				
78 40	Mc Connellsburg				
80 41	New Castle				
80 41	New Kensington				
75 40	Norristown				
80 41	Oil City				
81 42	Pennline				
75 40	Philadelphia				
80 40	Pittsburgh				
77 41	Port Royal				
76 41	Pottsville				
79 41	Punxsutawney				
76 40	Reading				
77 42	Sayre				
76 41	Scranton				
77 41	Selinsgrove				
81 41	Sharon				
79 40	Somerset				
79 41	St. Marys				
78 41	State College				
77 41	Sunbury				
79 42	Tionesta				
76 42	Tunkhannock				
80 40	Uniontown				
75 40	Upper Darby				
75 40	Warminster				
79 42	Warren				
81 40	West Alexander				
76 40	West Chester				
76 41	Wilkes-Barre				
77 41	Williamsport				
77 40	York				
RHODE ISLAND					
71 42	Bristol				
71 41	Newport				
71 42	Providence				
71 42	Warwick				
72 41	Westerly				
72 42	Woonsocket				
SOUTH CAROLINA					
82 34	Abbeville				
81 33	Allendale				
83 35	Anderson				
81 33	Barnwell				
80 35	Bennettsville				
80 34	Bishopville				
81 34	Camden				
81 34	Cameron				
81 34	Cayce				
80 33	Charleston				
80 35	Cheraw				
81 35	Chester				
82 33	Clearwater				
81 34	Columbia				
80 34	Darlington				
81 33	Denmark				
83 35	Easley				
82 34	Edgefield				
80 32	Edisto Beach				
80 34	Florence				
82 35	Gaffney				
79 33	Georgetown				
80 33	Goose Creek				
82 35	Greenville				
82 34	Greenwood				
81 33	Hampton				
81 32	Hardeeville				
81 32	Hilton Head Island				
83 34	Homeland Park				
80 34	Kingstree				
81 35	Lancaster				
82 34	Laurens				
81 35	Lockhart				
80 34	Manning				
79 34	Marion				
82 34	McCormick				
79 35	Minturn				
79 34	Myrtle Beach				
82 34	Newberry				
81 33	Orangeburg				
82 34	Saluda				
33 35	Seneca				
82 35	Spartanburg				
80 33	Summerville				
80 34	Sumter				
81 33	Walterboro				
81 34	Winnsboro				
81 35	York				
SOUTH DAKOTA					
98 45	Aberdeen				
98 44	Alexandria				
98 43	Armour				
104 45	Belle Fourche				
96 45	Big Stone City				
98 46	Britton				
97 44	Brookings				
104 46	Buffalo				
97 43	Canton				
99 44	Chamberlain				
98 45	Clark				
97 45	Clear Lake				
104 44	Custer				
98 44	De Smet				
102 45	Dupree				
101 45	Eagle Butte				
104 43	Edgemont				
97 45	Estelline				
102 45	Faith				
99 45	Faulkton				
97 44	Flandreau				
100 44	Fort Pierre				
99 44	Fort Thompson				
100 45	Gettysburg				
99 43	Gregory				
100 46	Herreid				
99 45	Highmore				
102 43	Hisle				
103 43	Hot Springs				
98 44	Howard				
98 44	Huron				
99 45	Ipswich				
102 44	Kadoka				
102 46	Lemmon				
99 46	Leola				
103 46	Ludlow				
97 44	Madison				
102 43	Martin				
101 46	McLaughlin				
99 45	Miller				
101 43	Mission				
98 44	Mitchell				
100 46	Mobridge				
101 44	Murdo				
103 45	Newell				
96 43	North Sioux City				
100 45	Onida				
97 43	Parker				
98 43	Parkston				
102 44	Philip				
100 44	Pierre				
103 43	Pine Ridge				
98 44	Plankinton				
100 44	Presho				
103 44	Rapid City				
99 45	Redfield				
97 44	Salem				

97 44 Sioux Falls
 97 46 Sisseton
 104 44 Spearfish
 98 43 Springfield
 96 44 Valley Springs
 97 43 Vermillion
 98 43 Wagner
 97 45 Watertown
 98 45 Webster
 99 44 Wessington Springs
 101 44 White River
 100 43 Winner
 98 44 Woonsocket
 97 43 Yankton

TENNESSEE

89 36 Alamo
 87 36 Ashland City
 85 35 Benton
 84 36 Blaine
 89 35 Bolivar
 82 37 Bristol
 89 36 Brownsville
 85 37 Byrdstown
 88 36 Camden
 86 36 Carthage
 86 37 Celina
 87 36 Centerville
 85 35 Chattanooga
 87 37 Clarksville
 85 35 Cleveland
 87 36 Columbia
 86 36 Cookeville
 90 36 Covington
 88 37 Crossland
 85 36 Crossville
 85 35 Dayton
 85 36 Decatur
 87 36 Dickson
 88 36 Dover
 85 35 Dunlap
 89 36 Dyersburg
 82 36 Elizabethton
 84 35 Englewood
 88 36 Erin
 82 36 Erwin
 87 35 Fayetteville
 87 36 Franklin
 86 36 Gainesboro
 83 36 Greeneville
 85 36 Harriman
 86 36 Hartsville
 89 35 Henderson
 87 36 Hendersonville

88 36 Hohenwald
 89 36 Humboldt
 89 36 Jackson
 85 36 Jamestown
 83 36 Jefferson City
 84 37 Jellico
 82 36 Johnson City
 83 37 Kingsport
 84 36 Knoxville
 86 37 Lafayette
 87 35 Lawrenceburg
 86 36 Lebanon
 84 36 Lenoir City
 87 35 Lewisburg
 88 36 Lexington
 88 36 Linden
 85 36 Livingston
 86 35 Lynchburg
 89 36 Martin
 84 36 Maryville
 84 36 Maynardville
 86 36 Mc Minnville
 89 36 Mckenzie
 90 35 Memphis
 83 36 Morristown
 82 36 Mountain City
 86 36 Murfreesboro
 87 36 Nashville
 83 36 Newport
 84 36 Oak Ridge
 84 36 Oliver Springs
 85 37 Oneida
 88 36 Paris
 88 36 Parsons
 85 36 Pikeville
 87 35 Pulaski
 90 36 Ripley
 88 35 Savannah
 89 35 Selmer
 84 36 Sevierville
 86 35 Shelbyville
 86 36 Smithville
 83 37 Sneedville
 89 35 Somerville
 89 37 South Fulton
 86 35 South Pittsburg
 85 36 Sparta
 85 36 Spencer
 87 37 Springfield
 84 36 Sweetwater
 84 36 Tazewell
 89 36 Tiptonville
 86 35 Tracy City
 86 35 Tullahoma

88 36 Waverly
 88 35 Waynesboro
 86 35 Winchester
 86 36 Woodbury

TEXAS

100 32 Abilene
 99 33 Albany
 98 28 Alice
 104 30 Alpine
 102 35 Amarillo
 95 30 Anahuac
 103 32 Andrews
 107 32 Anthony
 99 34 Archer City
 98 27 Armstrong
 100 33 Aspermont
 96 32 Athens
 94 33 Atlanta
 98 30 Austin
 100 32 Ballinger
 99 30 Bandera
 94 34 Barkman
 103 29 Basin Junction
 96 29 Bay City
 94 30 Beaumont
 98 28 Beeville
 101 31 Big Lake
 101 32 Big Spring
 98 30 Blanco
 99 30 Boerne
 96 34 Bonham
 101 36 Booker
 101 36 Borger
 105 30 Borrachio
 98 34 Bowie
 100 29 Brackettville
 99 31 Brady
 99 33 Breckenridge
 96 30 Brenham
 102 33 Brownfield
 97 26 Brownsville
 99 32 Brownwood
 96 31 Buffalo
 98 31 Burnet
 97 31 Caldwell
 98 28 Calliham
 97 31 Cameron
 100 30 Camp Wood
 100 36 Canadian
 96 33 Canton
 100 29 Carrizo Springs
 101 30 Carta Valley
 94 32 Carthage

104 29	Castolon	97 33	Fort Worth	95 33	Longview
94 32	Center	99 30	Fredericksburg	102 34	Lubbock
100 34	Childress	103 35	Friona	95 31	Lufkin
99 32	Cisco	101 33	Gail	96 31	Madisonville
101 35	Clarendon	97 34	Gainesville	97 31	Marlin
95 34	Clarksville	95 29	Galveston	94 33	Marshall
101 35	Claude	101 32	Garden City	99 31	Mason
97 32	Cleburne	98 28	George West	101 34	Matador
95 30	Cleveland	97 30	Giddings	102 31	Mc Camey
98 32	Clifton	95 33	Gladewater	98 26	McAllen
99 32	Clyde	98 32	Glen Rose	100 31	Menard
99 32	Coleman	99 31	Goldthwaite	104 32	Mentone
96 31	College Station	97 29	Goliad	101 31	Mertzon
101 32	Colorado City	97 30	Gonzales	96 32	Mexia
97 30	Columbus	99 33	Graham	101 36	Miami
99 32	Comanche	98 32	Granbury	102 32	Midland
95 30	Conroe	96 33	Greenville	95 33	Mineola
96 33	Cooper	97 29	Hallettsville	98 33	Mineral Wells
98 31	Copperas Cove	98 32	Hamilton	96 30	Missouri City
97 28	Corpus Christi	100 33	Hamlin	103 32	Monahans
96 32	Corsicana	100 33	Haskell	103 34	Morton
99 28	Cotulla	97 31	Hearne	95 33	Mount Pleasant
102 31	Crane	99 27	Hebbronville	103 34	Muleshoe
95 31	Crockett	94 31	Hemphill	100 33	Munday
100 34	Crowell	95 32	Henderson	95 32	Nacogdoches
100 29	Crystal City	98 34	Henrietta	96 30	Navasota
97 29	Cuero	102 35	Hereford	98 30	New Braunfels
95 33	Daingerfield	97 32	Hillsboro	94 31	Newton
103 36	Dalhart	99 29	Hondo	102 32	Odessa
97 33	Dallas	95 30	Houston	104 32	Old Christian Place
98 33	Decatur	96 31	Huntsville	94 30	Orange
101 29	Del Rio	98 33	Jacksboro	101 31	Ozona
105 32	Dell City	95 32	Jacksonville	100 34	Paducah
97 33	Denton	94 31	Jasper	96 32	Palestine
103 33	Denver City	101 33	Jayton	101 36	Pampa
102 35	Dimmitt	94 33	Jefferson	101 35	Panhandle
102 36	Dumas	100 30	Junction	96 34	Paris
100 29	Eagle Pass	98 29	Kenedy	99 29	Pearsall
96 30	East Bernard	103 32	Kermit	103 31	Pecos
100 31	Eden	99 30	Kerrville	101 36	Perryton
97 29	Edna	98 31	Killeen	95 33	Pittsburg
96 29	El Campo	98 31	Kingsland	102 34	Plainview
97 27	El Martillo	98 28	Kingsville	97 33	Plano
106 32	El Paso	97 30	La Grange	98 29	Pleasanton
101 31	Eldorado	106 31	La Isla	96 28	Port O'Conner
97 30	Elgin	95 29	Lake Jackson	97 28	Portland
96 33	Emory	101 35	Lakeview	101 33	Post
96 32	Fairfield	102 33	Lamesa	96 30	Prairie View
98 27	Falfurrias	98 31	Lampasas	100 34	Quanah
103 30	Farwell	100 28	Laredo	101 34	Ralls
100 34	Finney	102 34	Levelland	98 26	Raymondville
98 29	Floresville	102 34	Littlefield	97 28	Refugio
101 34	Floydada	95 31	Livingston	99 26	Rio Grande City
103 31	Fort Stockton	98 30	Lockhart	97 28	Rockport

96 33	Rockwall	UTAH	73 44	Randolph	
98 31	Round Rock	112 37	Alton	73 44	Rutland
100 31	San Angelo	109 37	Aneth	72 43	Springfield
98 29	San Antonio	113 38	Beaver	73 45	Swanton
94 32	San Augustine	109 38	Blanding	72 44	White River Junction
98 28	San Diego	110 37	Bluff		
98 30	San Marcos	109 40	Bonanza	VIRGINIA	
99 31	San Saba	112 41	Bountiful	82 37	Abingdon
102 30	Sanderson	114 40	Callao	77 39	Alexandria
96 30	Sealy	113 38	Cedar City	78 37	Amelia Court House
98 30	Seguin	112 38	Circleville	77 39	Annandale
103 33	Seminole	109 39	Cottonwood	79 37	Appomattox
99 34	Seymour	113 39	Delta	77 39	Arlington
100 35	Shamrock	113 40	Dugway	77 37	Barnetts
95 30	Shepherd	109 41	Dutch John	80 37	Bedford
97 34	Sherman	114 38	Enterprise	78 39	Berryville
94 30	Silsbee	112 39	Ephraim	83 37	Big Stone Gap
101 34	Silverton	114 39	Eskdale	78 37	Blackstone
101 33	Snyder	111 37	Halls Crossing	81 37	Bland
101 31	Sonora	111 41	Heber	80 39	Blue Grass
101 36	Spearmen	110 38	Hite	80 37	Blue Ridge
101 33	Spur	113 41	Hogup	81 37	Bluefield
100 33	Stamford	111 39	Huntington	77 38	Bowling Green
102 32	Stanton	113 37	Hurricane	82 37	Bristol
98 32	Stephenville	112 42	Logan	79 38	Buena Vista
101 32	Sterling City	110 39	Moab	76 37	Cape Charles
102 36	Stratford	112 41	Morgan City	78 38	Charlottesville
96 33	Sulphur springs	112 41	Ogden	76 37	Chesapeake
100 32	Sweetwater	112 38	Panguitch	77 37	Chester
102 33	Tahoka	111 41	Park City	75 38	Chincoteague
97 31	Temple	111 40	Price	80 37	Christiansburg
96 33	Terrell	112 40	Provo	77 37	Claremont
94 33	Texarkana	111 42	Randolph	80 38	Clifton Forge
99 33	Throckmorton	112 39	Richfield	82 37	Clintwood
95 31	Trinity	110 41	Roosevelt	77 38	Colonial Beach
102 35	Tulia	112 41	Salt Lake City	77 37	Colonial Heights
95 32	Tyler	113 42	Snowville	77 37	Courtland
100 29	Uvalde	114 37	St. George	80 38	Covington
104 31	Valentine	111 38	Torrey	78 38	Culpeper
105 31	Van Horn	110 40	Vernal	77 39	Dale City
102 35	Vega	114 41	Wendover	79 37	Danville
99 34	Vernon	114 42	Yost	76 38	Deltaville
97 29	Victoria			78 38	Dillwyn
97 32	Waco	VERMONT		78 37	Emporia
97 32	Waxahachie	73 45	Alburg	77 39	Falls Church
98 33	Weatherford	73 44	Barre	78 37	Farmville
100 35	Wellington	73 43	Bennington	78 38	Farmville (Cumberland)
98 34	Wichita Falls	73 43	Brattleboro	80 37	Floyd
95 33	Winnsboro	73 44	Burlington	77 37	Fort Lee
94 31	Woodville	72 45	Hardwick	77 37	Franklin
99 27	Zapata	72 45	Island Pond	77 38	Fredericksburg
		73 44	Middlebury	78 39	Front Royal
		73 45	Morrisville	81 37	Galax
		72 45	Newport	83 37	Gate City

[illegible]

78 39 Martinsburg
 79 39 Moorefield
 80 40 Morgantown
 81 40 Moundsville
 81 38 Mullens
 81 40 New Martinsville
 78 39 Oakland
 81 40 Paden City
 82 39 Parkersburg
 80 39 Parsons
 79 39 Petersburg
 80 39 Philippi
 82 39 Point Pleasant
 82 39 Ravenswood
 81 38 Richwood
 79 39 Romney
 81 39 Spencer
 80 37 Waiteville
 82 37 Welch
 81 39 West Union
 80 39 Weston
 81 40 Wheeling
 80 38 White Sulphur Springs
 79 40 Wiley Ford
 82 38 Williamson

WISCONSIN

87 45 Algoma
 92 45 Amery
 89 45 Antigo
 88 44 Appleton
 92 44 Arcadia
 91 47 Ashland
 88 46 Aurora
 90 43 Baraboo
 89 43 Beaver Dam
 89 42 Bergen
 89 44 Berlin
 91 44 Black River Falls
 90 47 Cedar
 91 45 Chippewa Falls
 89 46 Crandon
 90 43 Darlington
 90 43 Dodgeville
 92 45 Durand
 89 46 Eagle River
 91 45 Eau Claire
 88 44 Fond du Lac
 90 44 Friendship
 88 42 Genoa City
 93 46 Grantsburg
 88 45 Green Bay
 91 46 Hayward
 93 45 Hudson

88 43 Kenosha
 91 44 La Crosse
 91 45 Ladysmith
 89 43 Madison
 88 44 Manitowoc
 90 44 Mauston
 90 45 Medford
 92 45 Menomonie
 88 43 Mequon
 90 45 Merrill
 90 43 Middleton
 88 43 Milwaukee
 92 45 Mondovi
 90 43 Monroe
 89 44 Montello
 91 45 Neillsville
 89 45 Neopit
 88 44 New Holstein
 89 44 New London
 88 46 Niagara
 88 45 Oconto
 89 44 Oshkosh
 90 46 Park Falls
 90 43 Platteville
 89 44 Portage
 91 43 Prairie du Chien
 88 43 Racine
 89 46 Rhineland
 92 46 Rice Lake
 90 43 Richland Center
 93 45 River Falls
 89 45 Shawano
 88 44 Sheboygan
 92 46 Spooner
 90 45 Stevens Point
 87 45 Sturgeon Bay
 92 47 Superior
 91 44 Tomah
 91 44 Viroqua
 91 47 Washburn
 89 43 Watertown
 88 43 Waukesha
 90 45 Wausau
 89 44 Wautoma
 88 43 West Bend
 90 44 Wisconsin Rapids

WYOMING

104 45 Aladdin
 107 43 Alcova
 111 44 Alta
 108 41 Baggs
 110 45 Bannock Ford
 107 44 Buffalo
 106 43 Casper
 105 41 Cheyenne
 106 45 Clearmont
 109 45 Cody
 105 43 Douglas
 110 44 Dubois
 111 41 Evanston
 109 41 Firehole Canyon
 106 44 Gillette
 105 45 Hulett
 111 43 Jackson
 108 42 Jeffrey City
 111 42 Kemmerer
 110 42 La Barge
 109 43 Lander
 106 41 Laramie
 108 45 Lovell
 104 43 Lusk
 110 41 Lyman
 111 45 Mammoth
 106 42 Medicine Bow
 109 44 Meeteetse
 104 44 Newcastle
 104 41 Pine Bluffs
 110 43 Pinedale
 107 42 Rawlins
 108 43 Riverton
 109 42 Rock Springs
 107 41 Saratoga
 107 45 Sheridan
 108 44 Thermopolis
 104 42 Torrington
 105 44 Upton
 105 42 Wheatland
 108 44 Worland

APPENDIX B

Illuminance

The light of the Sun, Moon and night sky which reaches the surface of the Earth is modified by the atmosphere, which refracts, absorbs, polarizes and scatters the radiation passing through it in rather complex ways. For practical work it is often impossible to obtain measurements of atmospheric parameters that would be required to support a detailed and precise calculation of illuminance. Consequently, some general approximations must be made.

For the direct rays of the Sun or Moon, it is necessary to specify the location of each body relative to the point on the Earth in question. The mathematical methods adopted for the computer programs, tables and diagrams to provide altitude and azimuth are explained in textbooks on spherical astronomy (1,2) and are not reproduced here. Some additional considerations in the formulation, needed to compute illuminance, are discussed below.

The model for illuminance calculation recognizes three contributions at ground level: the direct rays of the Sun and Moon, indirect or skylight and the light of the night sky background. With the angular distance from the horizon of the Sun or Moon known, the effect of the atmosphere was modelled using the computed altitude as independent variable. For the direct rays of the Sun or Moon, the illuminance is that at the top of the atmosphere, reduced by the scattering and absorption of the mass of air along the light path to the surface. To approximate the atmosphere, we have adopted a spherical, homogeneous (or constant density) model; and for the air mass, the values determined by Bemporad (3) were fit. The formulation thus reduces to a simple differential equation, the solution of which introduces a parameter specifying the extinction of light per unit of air mass. To estimate the extinction coefficient, the data provided by Jones and Condit (4) as a result of their exhaustive study were used. The resulting expression for the direct rays is then a simple exponential formula, factored by the *sine* of the altitude to provide the horizontal component of illuminance by direct radiation.

For the light of the sky with direct rays excluded, the second contribution to total illuminance, a purely empirical representation was built up from the tables for indirect light provided by Jones and Condit. The tables give values for altitude ranging from the zenith to three degrees above the horizon.

Altitudes of the Sun closer to the horizon are of special importance in many applications; however. In order to model the situation near rising, setting and twilight, the formulas were extended to fit data collected and reduced by Brown (5), which provide light levels for solar altitude ranging from +90 deg. to -90

deg. The data published by Brown are of a different character than those of Jones and Condit. The separate contributions to illuminance by direct and scattered light are not distinguished. However, the data represent a more complete range of solar altitude, collected over a vast geographic area, and the final values are based on smoothing of an impressive number of measurements. The basic curve constructed by Brown is still relied upon for assessments of natural lighting and has appeared intact or enhanced in numerous studies and handbooks. But the original report by Brown is no longer readily accessible and his instrumental and reduction procedures are not well known. A digression in order to quote all relevant parts of his original report appears to be justified:

"Derivation of Basic Curve and Table. More than 12,000 measurements were made by the author in the Arctic, Antarctic, and the temperate and torrid zones of both hemispheres between January 1943 and May 1947. Photoelectric illuminometers manufactured by the General Electric Company were used for the measurement of light levels above one foot candle. Lower levels were measured by means of a Luckiesh-Taylor Brightness Meter and a calibrated test plate. The illuminometers were calibrated by the U.S. Bureau of Standards before and after the measurements were made. The brightness photometers were calibrated by the Nela Park Laboratory of the General Electric Company.

"The original data were plotted at large scale and a smooth curve was drawn. This basic curve was found to be in good agreement with fractional curves published in the scientific literature by Jones and Condit and others.

"The first plate (unnumbered) is the basic curve which gives the illumination as a function of solar altitude. The second plate (also unnumbered) is a table of illumination values corresponding to each degree of altitude of the sun from -90 to -21 degrees and from 65 to 90 degrees. Illumination values are given for each tenth of degree of solar altitude from -20 to 64 degrees. In most cases, the figures given are representative of the precision indicated; however, in the lowest levels of illumination, below 5×10^{-4} (when the sun is 19.5 degrees or more below the horizon), three significant figures are not justified by the data. Likewise, above 1000-foot candles (9.9 degrees solar altitude and above) the value of illumination is considered significant to no more than three figures although four are occasionally given in the table. Actually, the values given in the table were taken from a minute reading of the basic curve, greatly enlarged in scale, and present a truer picture of the curve than could be made by straight interpolation of the table had only two or three figures been given."

In regard to departures from a clear sky, Brown first notes that his basic graph refers to an average, not exceptionally, clear sky:

"Clear vs. Cloudy Conditions. The charts and tables contained herein, refer to light conditions during average clear days, clear days being defined as less than seven tenths overcast and with the sun's rays unobstructed to the locality in question.

When the sun is obstructed by thin clouds, the values given should be divided by two. For average cloud conditions obstructing the sun's rays, the values given for clear days should be divided by three. Occasionally, for dark stratus clouds preceding a heavy thunder storm, the values given should be divided by ten. However, this is not common."

The formula finally adopted in the present work represents the data of the two cited works for altitudes of the Sun from the zenith to that of nautical twilight. The third component of illuminance, which can vary unpredictably, has been represented by a constant, additive term equal to .0005 lux.

Thus far, what has been described applies to sunlight and the night sky. The same applies to illuminance by the Moon, with additional considerations. In addition to atmospheric attenuation of light, the Moon's illuminance depends upon its phase and its distance from the point on the Earth's surface being considered. For the phase function, the approximation derived by Lumme and Bowell (6) was adopted, using representative values of the multiple scattering factor and zero phase magnitude published by Lumme and Irvine (7) for the visible part of the spectrum. To account for the eccentricity of the lunar orbit and a topocentric (rather than geocentric) reference point, the ratio of mean to true distances was formulated and introduced as a factor of the Moon's illuminance. This is one exception to ordinary calculations of the Moon's position in which only the direction (altitude and azimuth) is of interest.

Another exception to the straightforward calculation for either the Sun or Moon should be noted. The usual situation in navigation, astronomy and other disciplines is one in which an observed altitude of the celestial body must be corrected for refraction in order to obtain a strictly geometric altitude. The calculation of air mass, needed for determination of extinction, requires apparent altitude; that is, the altitude affected by refraction. Theories and tables for refraction give corrections for the usual case: the reduction from observed to geometric altitude. Formulas derived by Bennett (8) are succinct and particularly attractive for such purposes. It was found that by changing one constant in Bennett's first approximate formula, his equation G, the same expression produced the amount of refraction to be added to the geometric altitude in order to obtain the apparent altitude required for the computation of air mass. The modified formula was coded into the computer routines of this work.

It is important to note a few of the limitations of the computer programs which have not been explicitly stated. Of the many factors which influence the real illuminance, it was not possible to include the effect of height above sea level, the moisture or dust content of air, the albedo of the ground itself, or the non-uniform distribution of illuminance from the sky (which may be important near times of sunrise or sunset). Also, isothermal and polytropic models of the atmosphere would be more realistic than the one adopted. That the criteria for factoring illuminance to accommodate cloud cover is questionable is acknowledged. However, the main purpose of the work is to provide manageable tools for ordinary

purposes and means. To include many of the refinements would be to expand the computer programs and to make their use both complicated and dependent on direct measurements of the atmosphere. In regard to the factors for clouds, it was thought best to maintain the criteria stated by Brown, since it does not seem possible to retrieve his original raw data and notes. But the factors are entered into the computer routines directly, so that it is entirely possible for a user to compare measured values of illuminance with computed, and to devise and apply a set of factors more suited to particular circumstances, without making any program changes.

With shortcomings noted, it is worthwhile to repeat a point that has been stated throughout: Calculated values of illuminance should be regarded with caution.

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6. Lumme, Kari and Bowell, Edward, *Astron. Jour.*, vol. 86, No. 11, Nov. 1981.
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